NSW GOVERNMENT

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 12

Air quality

transport.nsw.gov.au

DECEMBER 2020

12 Air quality

This chapter outlines the potential air quality impacts associated with the project and identifies measures which address these impacts. A detailed air quality impact assessment has been carried out for the project and is included in Appendix H (Technical working paper: Air quality).

An assessment of potential human health impacts associated with air quality is provided in Chapter 13 (Human health).

The Secretary's environmental assessment requirements as they relate to air quality, and where in the environmental impact statement these have been addressed, are detailed in Table 12-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to air quality are included in Section 12.7.

Table 12-1 Secretary's environmental assessment requirements – air quality

Secretary's requirements	Where addressed in EIS
Air quality	
1. The Proponent must undertake an air quality impact assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	**Appendix H** (Technical working paper: Air quality) documents the air quality impact assessment undertaken for the project in accordance with current guidelines. **Chapter 12** provides the air quality impacts related to the project. **Section 12.5** and **Section 12.6** outline the potential air quality impacts of the construction and operation of the project respectively.
2. The Proponent must ensure the AQIA also includes the following: a. Demonstrated ability to comply with the relevant regulatory framework, specifically the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010;	**Section 12.1** outlines information in respect to the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010. **Section 12.6** outlines the compliance of the project with relevant criteria and regulatory requirements.
b. The identification of all potential sources of air pollution including details of the location, configuration and design of all potential emission sources including ventilation systems and tunnel portals;	The methodology for identifying all potential sources of air pollution during construction and operation are outlined in **Section 12.2**. Details of potential sources of air pollution are provided in **Section 12.4**, **Section 12.5** and **Section 12.6**. The configuration and design of ventilation systems and tunnel portals are described and shown in **Chapter 5** (Project description).
c. A review of vehicle emission trends and an assessment that uses or sources	Best available information on vehicle emission trends are presented in **Section 12.4**.

Secretary's requirements	Where addressed in EIS
best available information on vehicle emission factors;	
d. An assessment of impacts (including human health impacts) from potential emissions from PM_{10}, $PM_{2.5}$, CO, NO_2, and other nitrogen oxides and volatile organic compounds (eg BTEX) including consideration of short and long term exposure periods;	An assessment of impacts of air pollutants during short and long term exposure periods are outlined in **Section 12.6**. Impacts to human health due to the operation of the project is provided in **Section 13.5** of **Chapter 13** (Human health).
e. Consider the impacts from the dispersal of these air pollutants on the ambient air quality along the proposal route, proposed ventilation outlets and portals, surface roads, ramps and interchanges and the alternative surface road network;	An assessment of impacts from the dispersal of air pollutants on ambient air quality along the project alignment is outlined in **Section 12.6**.
f. A qualitative assessment of the redistribution of ambient air quality impacts compared with existing conditions, due to the predicted changes in traffic volumes;	A qualitative assessment of the redistribution of ambient air quality impacts in comparison to existing conditions is presented in **Section 12.6.3**.
g. Assessment of worst case scenarios for in-tunnel and ambient air quality, including a range of potential ventilation scenarios and range of traffic scenarios, including worst case design maximum traffic flow scenarios (variable speed) and the worst case breakdown scenario, and discussion of the likely occurrence of each;	**Section 12.6** outlines the assessment of in-tunnel air quality in addition to the assessment of issues related to ambient air quality.
h. Details of the proposed tunnel design and mitigation measures to address in-tunnel air quality and the air quality in the vicinity of portals and any mechanical ventilation systems (ie ventilation outlets and air inlets) including details of proposed air quality monitoring (including frequency and criteria);	Details of the proposed tunnel design and monitoring are presented in **Chapter 5** (Project description), while mitigation and management measures in relation to in-tunnel air quality and air quality in the vicinity of portals and mechanical ventilation systems are outlined in **Section 12.7.2**.
i. A demonstration of how the project and ventilation design ensures that concentrations of air emissions meet NSW, national and international best practice for in-tunnel and ambient air quality, and taking into consideration the approved criteria for the M4 East project, New M5 project and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy;	Information relating to the design standard of the proposed ventilation system for the project is provided in **Chapter 5** (Project description). Criteria applied in this assessment are discussed in **Section 12.1** and **Section 12.3**. The project and ventilation system have been designed to meet in-tunnel criteria and ambient air quality goals and criteria as outlined in **Section 12.3**.
j. Details of any emergency ventilation systems, such as air intake/exhaust outlets, including protocols for the operation of these systems in	Details of any emergency ventilation systems, such as air intake/ventilation outlets, including protocols for the operation of these systems in emergency situations, potential emission of air

Secretary's requirements	Where addressed in EIS
emergency situations, potential emission of air pollutants and their dispersal, and safety procedures;	pollutants and their dispersal, and safety procedures are presented in **Chapter 5** (Project description).
k. Details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures or for the exclusion of other measures;	Details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures or for the exclusion of other measures are outlined in **Section 12.7.2** and expanded upon in **Chapter 5** (Project description). **Chapter 4** (Project development and alternatives), **Section 4.5** provides the ventilation system design alternatives.
l. A description and assessment of the impacts of potential emission sources relating to construction, including details of the proposed mitigation measures to prevent the generation and emission of dust (particulate matter and TSP) and air pollutants (including odours) during the construction of the proposal, particularly in relation to ancillary facilities (such as concrete batching plants), dredge and tunnel spoil handling and storage, the use of mobile plant, stockpiles and the processing and movement of spoil; and	A description and assessment of impacts relating to potential emission sources relating to construction are outlined in **Section 12.5**, while mitigation measures to prevent the generation and emission of dust and other air pollutants (including odours) are presented in **Section 12.7.1** of this chapter.
m. A cumulative assessment of the in-tunnel, local and regional air quality impacts from the operation of the project and due to the operation of and potential continuous travel through motorway tunnels and surface roads.	The cumulative assessment of the in-tunnel, local and regional air quality impacts, as well as consideration of continuous travel through motorway tunnels, is outlined in **Section 12.6**.

12.1 Legislative and policy framework

The *Protection of the Environment Operations Act 1997* (NSW) allows the NSW Environment Protection Authority to regulate air emissions in NSW. Further, it specifies that road tunnel emissions are regulated by the NSW Environment Protection Authority. The Secretary's environmental assessment requirements for the project refer to the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010. Although the Protection of the Environment Operations (Clean Air) Regulation 2010 specifies concentration limits for air emissions, these limits are designed primarily for industrial activities and the limit values are much higher than those imposed for motorway tunnels in Sydney.

The monitoring and management of dust emissions during construction and the ventilation outlet emissions during operation would be regulated under an Environment Protection Licence prescribed under the *Protection of the Environment Operations Act 1997*.

In February 2018, the NSW Government announced stronger measures on emissions from motorway tunnels and then established a new process for the assessment, determination, and compliance of significant road tunnels (and associated ventilation systems). The process, which applies to this project, is summarised below:

- Prior to public exhibition of the environmental impact statement:

- The Office of the Chief Scientist and Engineer (OCSE) provides a scientific review of a project's air emissions from ventilation outlets for the Minister of Planning and Public Spaces' consideration
- The NSW Chief Health Officer releases a statement on the potential health impacts of emissions from the tunnel ventilation outlets informed by the review by the OCSE

- The NSW Environment Protection Authority provides technical advice to the Department of Planning, Industry and Environment on operational air quality impacts during the assessment of the environmental impact statement
- The Department of Planning, Industry and Environment seeks advice from an independent air quality expert during the assessment of the environmental impact statement, if required
- If the project is approved, the Department of Planning, Industry and Environment regulates the construction and operation of the project in accordance with the project approval
- The NSW Environment Protection Authority licenses emissions from the ventilation outlets under the *Protection of the Environment Operations Act 1997*.

As part of the preparation of the air quality impact assessment for the project, Appendix H (Technical working paper: Air quality) was issued to the Office of the Chief Scientist and Engineer on 26 October 2020, and the Advisory Committee on Tunnel Air Quality (ACTAQ) coordinated a scientific review of the project's air emissions from ventilation outlets.

For the operating years of the project, nitrogen dioxide (NO_2) would be the pollutant that determines the required airflow and drives the design of the tunnel ventilation system. In February 2016, the ACTAQ issued a policy entitled *'In-tunnel air quality (nitrogen dioxide) policy'* (ACTAQ, 2016). The policy consolidates the approach taken for similar projects (NorthConnex, New M4 and M8 Motorway), and requires tunnels to be 'designed and operated so that the tunnel average NO_2 concentration is less than 0.5 parts per million (ppm) as a rolling 15 minute average'. In 2018, ACTAQ released *Technical Paper TP07: Criteria for In-tunnel and Ambient Air Quality* (ACTAQ, 2018a), which concluded that the NO_2 criterion is the most stringent in Australia and compares favourably to the international in-tunnel NO_2 design guidelines which range from between 0.4 ppm to 1 ppm. The ventilation system would be designed to achieve this criterion.

With regards to regional air quality, the NSW Environment Protection Authority has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). This procedure was applied to the air quality impact assessment of the project to give an indication of the likely significance of the project's effect on ozone concentrations in the broader Sydney region.

The in-tunnel and ambient air quality assessment was carried out against criteria, or levels of pollutants, that have been adopted by the NSW Government. Schedule 4 of the Protection of the Environment Operations (Clean Air) Regulation 2010 specifies standards of concentrations for general activities and plant. The project was assessed against the air quality criteria listed in the *Modelling and Assessment of Air Pollutants in NSW* (NSW EPA, 2016) (NSW EPA Approved Methods) as the statutory method used for assessing air pollution from stationary sources.

Odour emissions would be assessed and managed in accordance with the *Technical framework for the assessment and management of odour from stationary sources in NSW* (DEC, 2006a). This framework introduces a system that protects the environment and the community from the impacts of odour emissions, while promoting fair and equitable outcomes for the operators of activities that emit odour.

12.2 Assessment methodology

12.2.1 Overview

The assessment methodology for air quality impacts has included the following key tasks:

- Assessment of potential dust impacts and odour impacts on sensitive receivers during construction of the project
- Assessment to ensure the tunnel ventilation system can achieve acceptable in-tunnel air quality outcomes for carbon monoxide, nitrogen dioxide and visibility during operation of the project
- Modelling of changes in the concentrations of key pollutants at community, residential, workplace and recreational receiver locations for expected traffic and operation of the project under a number of worst case operational scenarios
- Assessment of regional air quality impacts associated with the operation of the project
- Prediction of changes in the levels of three representative odorous pollutants (toluene, xylenes, and acetaldehyde) at receivers with the operation of the project.

The methodology for the assessment of both construction and operational air quality impacts, as well as the modelling inputs and assumptions used to carry out this assessment is provided in full at Appendix H (Technical working paper: Air quality).

12.2.2 Construction air quality assessment methodology

Air quality impacts as a result of construction of the project include those associated with exhaust emissions from tunnelling operations, and from the generation of dust and odour.

Exhaust emissions during construction would occur due to the use of some plant and equipment. These impacts are considered to be minor and unlikely to have a noticeable impact on the surrounding environment including sensitive receivers. Any impacts associated with exhaust emissions would be managed through the environmental management measures described in Section 12.7.

Some construction activities could also result in the generation of dust and odours. The assessment methodology for the air quality impacts associated with the generation of dust and odour are described below.

Dust assessment

For the purpose of the construction dust assessment, construction activities have been categorised into four types to reflect their potential impacts:

- Demolition is any activity that involves the removal of existing structures
- Earthworks covers the processes of topsoil stripping, ground levelling, excavation (including blasting) and landscaping and primarily involves excavating, loading, hauling, tipping and compaction of material including stockpiling where required
- Construction is any activity that involves the provision of new structures, or modification or refurbishment of existing structures, including buildings, ventilation outlets and roads
- Track-out involves the transport of dust and dirt from the construction/demolition site onto the public road network using construction vehicles. These materials may then be deposited and re-suspended by vehicles using the road network.

It is difficult to quantify dust emissions from construction activities since it is not possible to predict the weather conditions that would prevail during specific construction activities. The effects of construction on airborne particulate matter would generally be temporary and of relatively short duration, and mitigation should be straightforward since dust suppression measures are routinely employed as ‘good practice’ at most construction sites.

A semi-quantitative, risk-based approach was used for the assessment in accordance with the United Kingdom Institute of Air Quality Management’s *Guidance on the assessment of dust from demolition and construction* (Institute of Air Quality Management (IAQM), 2014). The IAQM guidance has been adapted for use in NSW, taking into account factors such as the assessment criteria for ambient PM_{10} (being particulate matter less than or equal to 10 micrometres in diameter) concentrations. The potential construction air quality impacts were assessed based on the proposed works, plant and equipment, and the potential emission sources and levels. The assessment considered the risk of dust deposition and elevated concentrations of dust (as PM_{10}) in the air from construction activities, and potential impacts on amenity, human health and the environment.

The IAQM guidance (IAQM, 2014) specifies that a dust assessment is required where:

- Human receivers are within 350 metres of the assessment zone boundary. A human receiver refers to any location where a person or property may experience the adverse effects of airborne dust or dust settlement, or exposure to dust emissions over a time period that is relevant to air quality standards and goals
- Ecological receivers are within 50 metres of the boundary of the assessment zone. An ecological receiver refers to any sensitive habitat or fauna affected by dust settlement.

Key steps in the assessment included:

- An initial screening to identify whether there is a risk of construction dust impacts based on the proximity of human and ecological receivers to construction activities
- A risk assessment to determine which construction activities have the potential to generate a dust impact based on the scale and nature of the activities, and the sensitivity of nearby human and ecological receivers
- Identification of appropriate dust mitigation and management measures depending on the level of assessment risk of impact.

Further details of the construction dust assessment methodology are provided in Appendix H (Technical working paper: Air quality) of this environmental impact statement. The assessment of construction dust using the IAQM guidance (IAQM, 2014) is outlined in Figure 12-1. The construction dust assessment carried out for the project is summarised in Section 12.5.1.

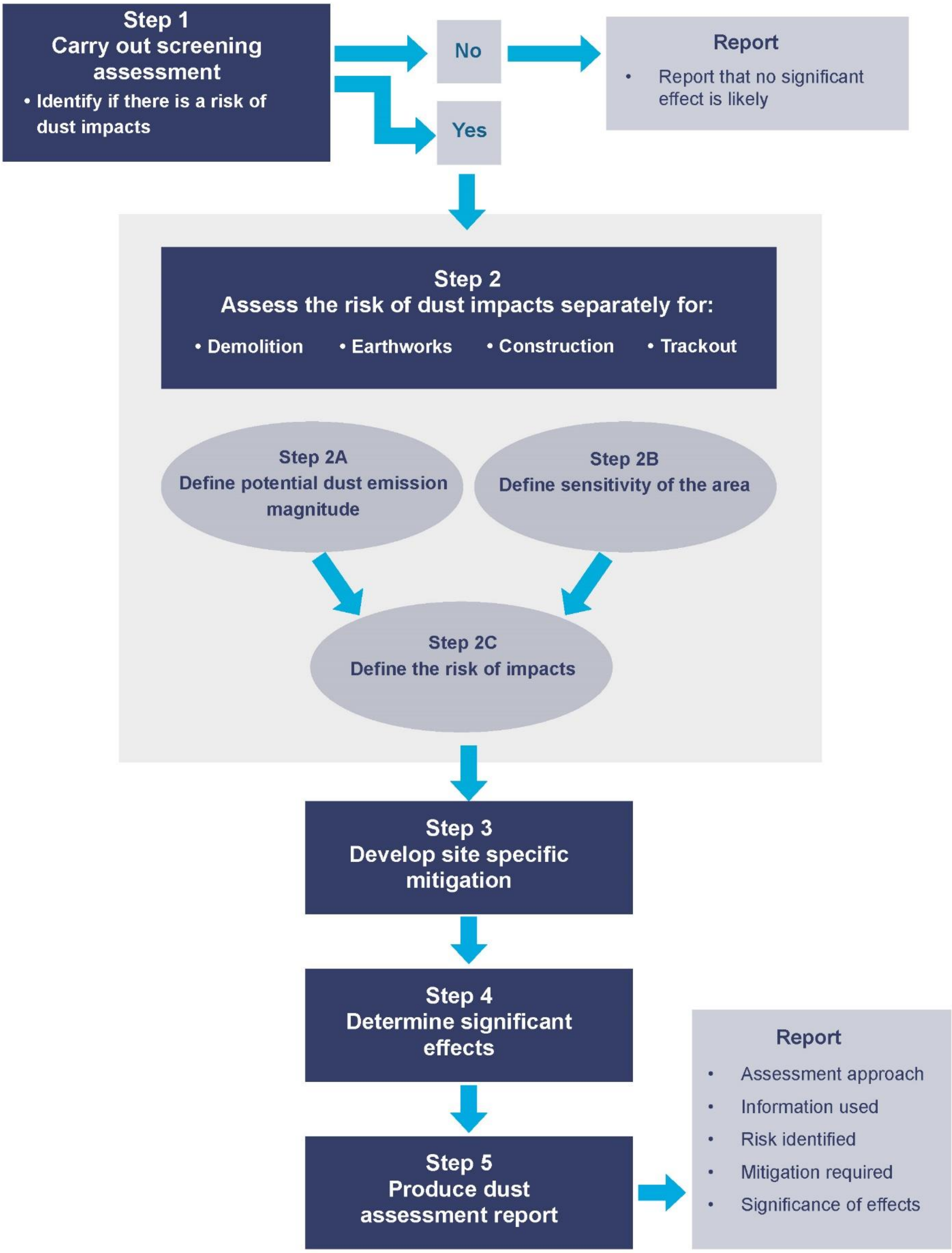

Figure 12-1 Construction dust assessment procedure (IAQM, 2014)

Odour assessment

During construction, there is the potential for odour impacts due to emissions from dredged or excavated material being exposed to air, temporarily stored and transported for treatment or disposal to landfill. As a location for temporary storage would be determined during detailed design, a qualitative assessment of odour impacts has been carried out and is discussed in Section 12.5.

12.2.3 Operational air quality assessment methodology

Air quality impacts from the operation of the project are associated with emissions from vehicles using the project. The impact of vehicle emissions was considered in terms of effects on in-tunnel air quality, local air quality, regional air quality and odour.

In-tunnel air quality

The tunnel ventilation system would be operated to achieve acceptable in-tunnel air quality outcomes for carbon monoxide (CO), NO_2 and visibility (as a measure of in-tunnel particulate matter concentrations) (refer to Section 12.3.2 for additional information relating to air quality criteria).

In-tunnel air quality modelling was carried out using IDA Tunnel software. The modelling considered traffic volumes, tunnel air flow and vehicle emission levels. The modelling incorporated the Beaches Link, Western Harbour Tunnel and WestConnex projects and considered the following scenarios:

- Expected traffic – 24-hour operation of the project ventilation system under day-to-day conditions of expected traffic demand in 2027 (planned opening date) and 2037
- Worst case traffic – the most onerous traffic conditions for the ventilation system (refer below)
- Travel route scenarios – a worst case trip scenario for in-tunnel exposure to NO_2.

Operational worst case scenarios

Operational worst case scenarios consider emissions from traffic within the tunnels and represent the theoretical maximum pollutant concentrations for all potential traffic operations in the tunnel, including unconstrained traffic conditions from an emissions perspective, as well as vehicle breakdown situations. The operational worst case scenarios are conservative and result in pollutant emission concentrations that are much higher than those that could occur under any foreseeable operational conditions in the tunnel.

The operational worst case assessments of in-tunnel air quality considered worst case (variable speed) traffic operations and worst case (breakdown or major incident) operations.

The worst case (variable speed) traffic operation scenario represents the upper limit of daily operations on the ventilation system of the mainline and ramp tunnels, regardless of the year of operation and is based on the traffic flow splits of the predicted traffic peak periods with the tunnels reaching a theoretical maximum lane capacity traffic flow rate. This scenario also includes the highest predicted number of buses using the tunnels. The worst case (variable speed) traffic operation scenario was considered under four different average speeds for lane capacity; 20, 40, 60 and 80 kilometres per hour.

The worst case (breakdown or major incident) operation scenario assesses the most conservative case from a traffic perspective, where congestion that occurs as a result of a breakdown affects the longest length within the mainline and ramp tunnels. This worst case operational scenario assumes a breakdown would result in a complete blockage on the specific ramp causing traffic that would ordinarily use the mainline tunnel to take other routes.

In-tunnel air quality for extended journeys

The assessment for in-tunnel air quality for extended journeys considers the estimated average concentration of NO_2 for the longest potential journey that could be taken by motorists in the connected motorway network. This was identified as a journey that used the project, the Western Harbour Tunnel, WestConnex and the M6 Motorway (Stage 1) tunnel network.

Provided that each project satisfies the air quality criteria (which requires NO_2 concentrations to be below an average of 0.5 ppm over the trip length through each tunnel), the average through the entire network would remain at, or below, 0.5 ppm under all traffic conditions. For this assessment, the estimated journey assessment completed as part of the *WestConnex M4-M5 Link environmental impact statement* (Roads and Maritime Services, 2017a) has been combined with the in-tunnel modelling completed for the 'Do something cumulative 2037' scenario.

Ambient air quality

The potential impacts of the project on ambient air quality during operation were assessed in relation to CO, NO_2, PM_{10} and $PM_{2.5}$ (particulate matter less than or equal to 2.5 micrometre diameter) and air toxics (benzene, polycyclic aromatic hydrocarbons (PAHs), formaldehyde, 1,3-butadiene and ethylbenzene), in accordance with the NSW EPA Approved Methods or the *National Environment Protection (Ambient Air Quality) Measure* (National Environment Protection Council (NEPC), 2003b) as relevant. The pollutants and criteria considered are provided in Section 12.3.3.

The following terms have been used to describe the concentration of pollutants at a specific location or receiver:

- Background concentration describes all contributing sources of a pollutant concentration other than road traffic. It includes contributions from natural sources, industry and domestic activity
- Surface road concentration describes the contribution of pollutants from the surface road network. It includes not only the contribution of the nearest road at the receiver, but also the net contribution of the rest of the modelled road network at the receiver
- Tunnel portal concentration is the contribution from the portals of existing tunnels for which portal emissions are permitted (Sydney Harbour Tunnel and Eastern Distributor tunnel)
- Ventilation outlet concentration describes the contribution of pollutants from tunnel ventilation outlets
- Total concentration is the sum of the sources defined above: background, surface road and ventilation outlet concentrations. It may relate to conditions with or without the project under assessment
- The change in concentration due to the project is the difference between the total concentration with the project and the total concentration without the project (increase or decrease), depending on factors such as the redistribution of traffic on the network as a result of the project.

The modelling scenarios, modelling process, receivers considered and approach to the analysis of results are discussed below.

Modelling scenarios

Seven expected traffic scenarios were included in the operational air quality assessment and considered future changes in the composition and performance of the vehicle fleet, as well as predicted traffic speeds, traffic volumes and the distribution of traffic on the road network. Each expected traffic scenario is set out in Chapter 9 (Operational traffic and transport) and has been modelled from an air quality perspective in order to assess the potential air quality impacts of the traffic scenario. The expected traffic scenarios that were modelled are summarised in Table 12-2.

Table 12-2 Operational air quality assessment modelling – expected traffic scenarios

Scenario	Existing network	Western Harbour Tunnel and Warringah Freeway Upgrade	Beaches Link and Gore Hill Freeway Connection	WestConnex	Other projects		
					Sydney Gateway	M6 Motorway (Stage 1)	M6 Motorway (full project)
Scenario in the base year (2016)							
Base year (existing conditions)	✓	-	-	-	-	-	-
Scenarios at project opening (2027)							
'Do minimum 2027' (without the project)	✓	-	-	✓	-	-	-
'Do something 2027' (with the project)	✓	Warringah Freeway Upgrade only	✓	✓	-	-	-
'Do something cumulative 2027' (with the project and other projects)	✓	✓	✓	✓	✓	✓	-
Scenarios ten years after the project opening (2037)							
'Do minimum 2037' (without the project)	✓	-	-	✓	-	-	-
'Do something 2037' (with the project)	✓	Warringah Freeway Upgrade only	✓	✓	-	-	-
'Do something cumulative 2037' (with the project and other projects)	✓	✓	✓	✓	✓	-	✓

Modelling process

The modelling process involved an emissions model, a meteorological model (Graz Mesoscale Model – GRAMM) and a dispersion model (Graz Langrangian Model – GRAL). The relationship between these models is illustrated in Figure 12-2.

For each expected traffic scenario, a spatial emissions inventory (emissions model) was developed for road traffic sources within the domain of the dispersion model. The following components were treated separately to take into account potential changes in traffic emissions across the road network:

- Emissions from existing and proposed tunnel ventilation outlets for tunnels where portal emissions are, or would not be, conducted
- Emissions from the portals of a small number of existing tunnels, where these are currently conducted
- Emissions from the traffic on the surface road network, including any new surface roads associated with the project.

The GRAMM meteorological model predicted wind fields (three-dimensional spatial pattern of winds). Predicted wind fields then became an input into the dispersion model following alignment with meteorological observations.

The GRAL dispersion model predicted ground-level pollutant concentrations by simulating the movement of individual 'particles' of a pollutant emitted from an emission source in a three-dimensional wind field.

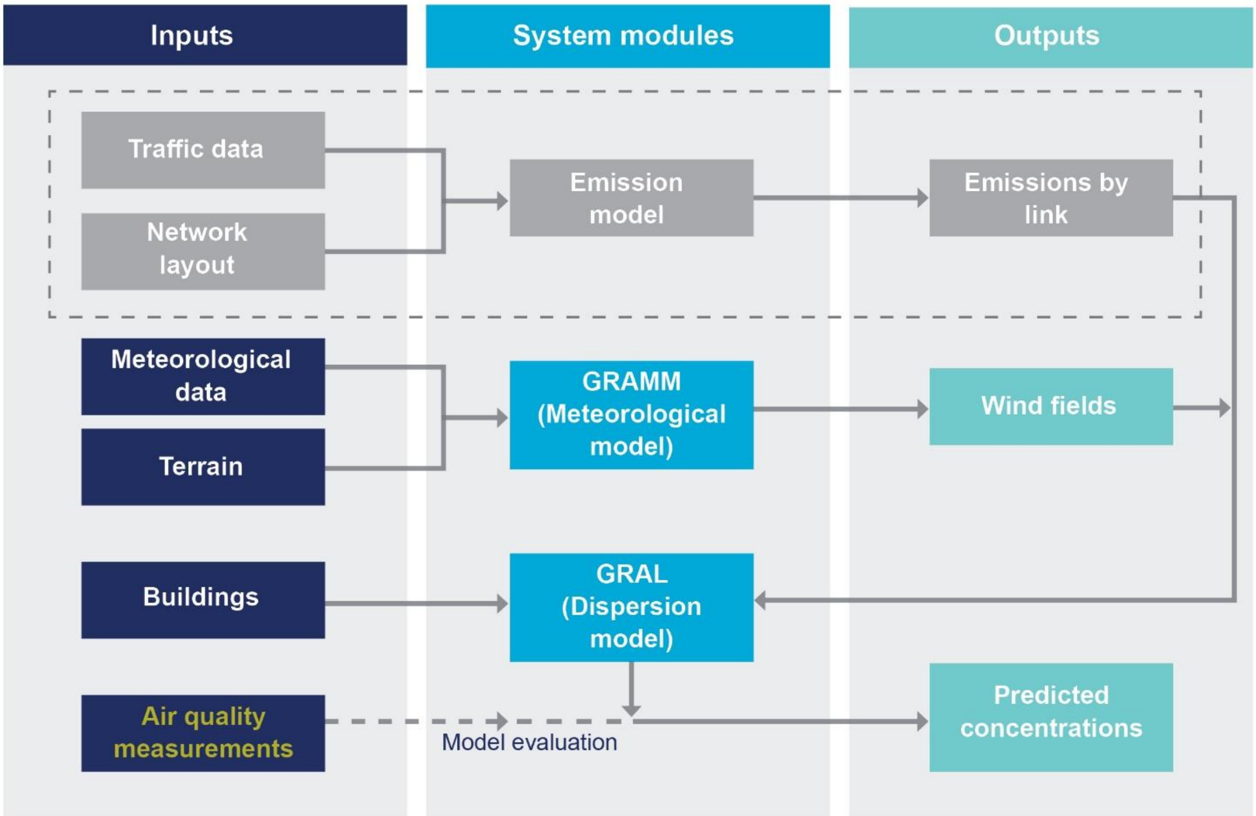

Figure 12-2 Overview of operational air quality modelling process

Receivers

Receivers are defined as anywhere someone works or resides, or may work or reside, including residential areas, hospitals, hotels, shopping centres, playgrounds and recreational centres. Due to its location in a highly built-up area, the dispersion modelling domain for the project contains many receivers.

Two types of receivers were considered in the air quality assessment:

- 'Community receivers'. These were taken to be representative of particularly sensitive locations such as schools, child care centres and hospitals within a zone up to 1.5 kilometres either side of the Western Harbour Tunnel and Beaches Link program of works corridor, and generally near significantly affected roadways. In total, 42 community receivers were included in the assessment (refer to Figure 12-3)
- 'Residential, workplace and recreational receivers'. These were all discrete receiver locations along the Western Harbour Tunnel and Beaches Link program of works corridor, and mainly covered residential and commercial land uses. A maximum of 35,484 residential, workplace and recreational receiver locations were considered in the assessment of project air quality impacts.

The identified community and residential, workplace and recreational receiver locations were representative and not exhaustive. They have been selected using professional judgement to demonstrate potential impacts at a more detailed level. While some sensitive locations might not have been selected as representative community receivers, they have still been assessed as residential, workplace and recreational receivers in the model. For example, while the Northern Beaches Secondary College – Balgowlah Boys Campus has not been included as a community receiver, the potential air quality impacts at that location have been predicted and are considered in the discussion of results for residential, workplace and recreational receivers below in Section 12.5 and Section 12.6.

The main emphasis in the assessment was on ground-level concentrations (as specified in the NSW EPA Approved Methods). However, at several locations there are existing multi-storey residential and commercial buildings, or the land zoning permits the construction of such buildings, and the potential impacts of the project at these elevated points are likely to be different to the impacts at ground level. Elevated receivers were therefore evaluated separately.

Based on a review of available building height information, four elevated receiver heights were selected to cover both existing buildings and future developments: 10 metres, 20 metres, 30 metres and 45 metres.

The modelling extent extended beyond the project to allow for the traffic interactions between the Western Harbour Tunnel and Warringah Freeway Upgrade and the WestConnex M4-M5 Link projects, as well as changes along affected surface roads. A large model extent also increased the number of meteorological and air quality monitoring stations that could be included for model evaluation purposes.

Regional air quality

The potential impacts of the project on air quality more widely across Greater Sydney were assessed through consideration of the changes in emissions across the road network. The regional air quality impacts of a project can also be considered in terms of its capacity to influence ozone production. As noted in Section 12.1, The NSW Environment Protection Authority has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). Although this procedure does not relate specifically to road projects, it was applied here to give an indication of the likely significance of the project's effect on ozone concentrations in the Greater Sydney region.

Odour

The generation of odours from motor vehicle emissions tend to be very localised and short-lived, and there are unlikely to be any significant, predictable or detectable changes in odour due to the project. Odour was assessed based on the maximum change in 1-hour total hydrocarbon concentrations as a result of the project, which was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes and acetaldehyde). These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

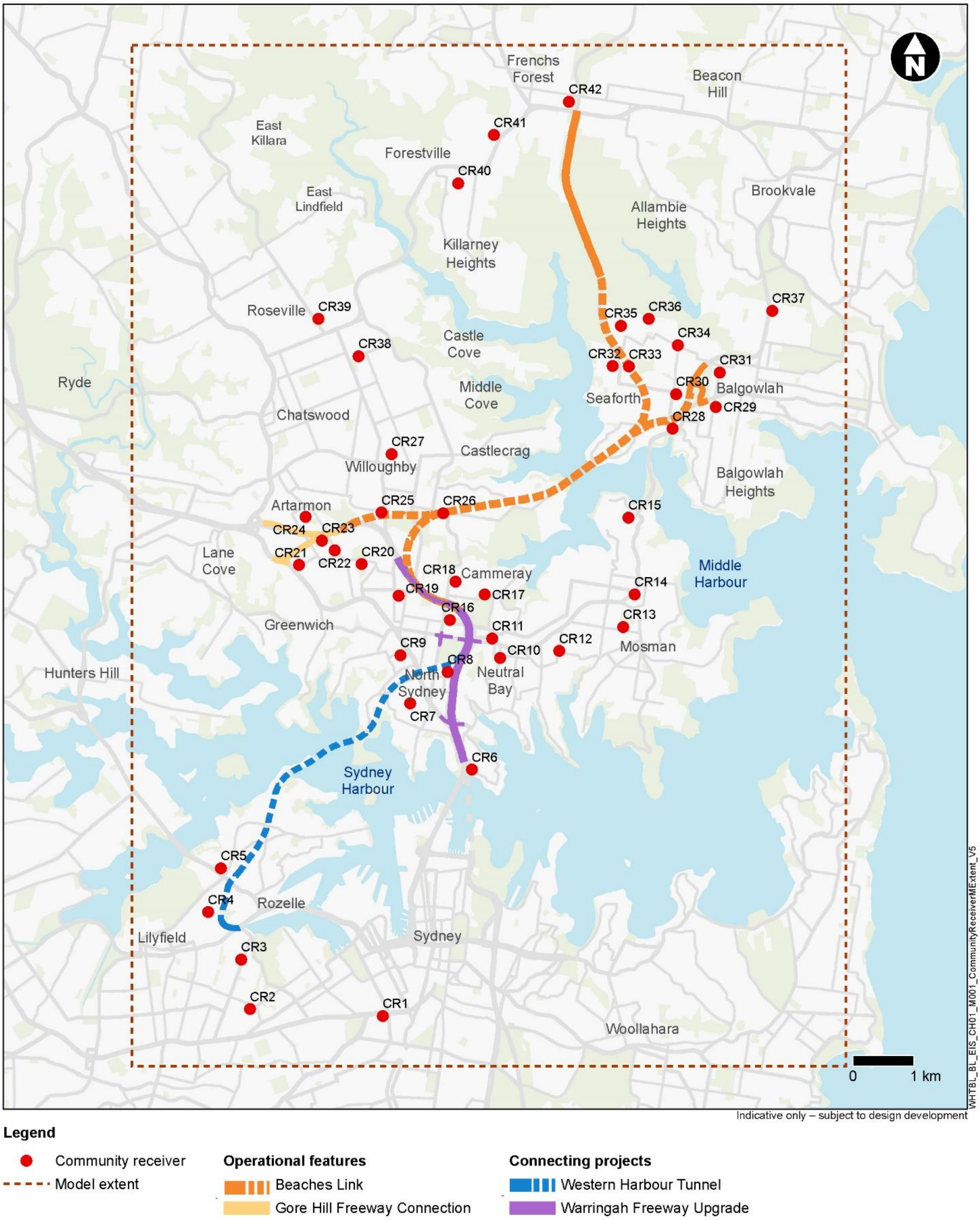

Figure 12-3 Location of community receivers and model extent

12.3 Criteria and standards

12.3.1 Overview

There are two types of criteria and standards that are relevant to the assessment of air quality impacts from construction and operation of the project:

- In-tunnel air quality criteria, which apply to the air quality inside the mainline tunnels
- Ambient air quality criteria and standards, which apply to outdoor air quality.

Air quality criteria and standards applied to the assessment of the project are outlined in the following sections, with further details provided in Appendix H (Technical working paper: Air quality).

12.3.2 In-tunnel air quality criteria

The project has been designed to achieve in-tunnel air quality that is protective of human health and amenity and provides a safe travel environment. Further details of the project's ventilation system design are provided in Chapter 5 (Project description).

The project's ventilation system would be operated to achieve the in-tunnel air quality criteria summarised in Table 12-3. The in-tunnel air quality limits for the project reflect those identified by the ACTAQ (ACTAQ, 2016; ACTAQ, 2018a) and are consistent with the limits provided in planning approvals for recent motorway tunnel projects in NSW.

Table 12-3 In-tunnel operational limits for CO, NO_2 and visibility

Parameter	Averaging period	Criteria
CO	3-minute (rolling), single point exposure limit	200 ppm
	15-minute (rolling), average along tunnel length	87 ppm
	30-minute (rolling), average along tunnel length	50 ppm
NO_2	15-minute (rolling), average along tunnel length	0.5 ppm
Visibility	15-minute (rolling), at any point in the tunnel	0.005 m^{-1}

12.3.3 Ambient air quality criteria

Air quality criteria and standards applied to the assessment of the project are outlined in the following sections, with further details provided in Appendix H (Technical working paper: Air quality), including Annexure B of that report.

Air pollutant criteria

The ambient air quality criteria applied to the assessment of the project are set in the NSW EPA Approved Methods and summarised in Table 12-4. Some of these criteria are among the lowest in the world (see Annexure B of Appendix H (Technical working paper: Air quality)). For example, the annual average $PM_{2.5}$ criterion used, on which a key health metric is based, is lower than any other $PM_{2.5}$ standard in the world, including the World Health Organisation guideline.

Table 12-4 Ambient air quality criteria applied to the assessment of the project

Pollutant	Criteria	Averaging period
CO	30 mg/m^3	1 hour
	10 mg/m^3	8 hours (rolling)

Pollutant	Criteria	Averaging period
NO_2	246 µg/m^3	1 hour
	62 µg/m^3	1 year
PM_{10}	50 µg/m^3	24 hours
	25 µg/m^3	1 year
$PM_{2.5}$	25 µg/m^3	24 hours
	20 µg/m^3 (goal by 2025)	24 hours
	8 µg/m^3	1 year
	7 µg/m^3 (goal by 2025)	1 year
Benzene[1]	0.029 mg/m^3	1 hour
Polycyclic aromatic hydrocarbons (PAHs) (as benzo(a)pyrene)[1]	0.0004 mg/m^3	1 hour
Formaldehyde[1]	0.02 mg/m^3	1 hour
1,3-butadiene[1]	0.04 mg/m^3	1 hour
Ethylbenzene[1]	8 mg/m^3	1 hour

Note 1: These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles

Odour criteria

The NSW EPA Approved Methods provides assessment criteria for complex mixtures of odorous compounds, as summarised in Table 12-5. These criteria are 99th percentile values, meaning that they must not be exceeded more than one per cent of the time.

Table 12-5 Assessment criteria for odour

Population of affected community	Criterion for complex mixtures of odour (OU)
≤~2	7
~10	6
~30	5
~125	4
~500	3
Urban (>2000) and/or schools and hospitals	2

For the assessment of operational odour impacts, the change in the maximum 1-hour total hydrocarbon concentration as a result of the project was calculated at each of the residential, workplace and recreational receiver locations. The hydrocarbon pollutants were taken to be representative of other odorous pollutants from motor vehicles. The odorous pollutants assessed along with their relevant criteria include:

- Toluene (360 µg/m^3)
- Xylene (190 µg/m^3)
- Acetaldehyde (42 µg/m^3).

12.4 Existing environment

Air quality in a region is influenced by a number of factors including the terrain, meteorology (weather patterns), historical trends in road traffic emissions and the current (ambient) and historical air quality environment.

12.4.1 Meteorology

Analysis of meteorological data found that the Randwick station (operated by the Department of Planning, Industry and Environment (Environment, Energy and Science)) was the most representative of the project corridor. At Randwick, the wind speed and wind direction patterns over the five-year period between 2011 and 2016 were reasonably consistent. Average wind speeds ranged from 2.4 to 2.6 meters per second.

12.4.2 Vehicle emissions

The most comprehensive source of information on current and future air pollutant emissions in the Sydney area is the emissions inventory that is compiled periodically by the NSW Environment Protection Authority.

For 2016, the emissions inventory identifies that road transport, including cars, light duty vehicles, heavy duty vehicles such as buses and trucks and other transport such as motorbikes, was the second largest sectoral contributor to emissions of CO (34 per cent) and the largest contributor to NO_X (47 per cent) in Sydney. The sector was also responsible for substantial proportions of emissions of volatile organic compounds (13 per cent), PM_{10} (nine per cent) and $PM_{2.5}$ (10 per cent). Road transport contributed only two per cent of total sulfur dioxide (SO_2) emissions in Sydney, reflecting the reduced sulfur in road transport fuels in recent years.

Petrol passenger vehicles (mainly cars) accounted for a large proportion of the vehicle kilometres travelled in Sydney and exhaust emissions from these vehicles were responsible for 65 per cent of CO from road transport in Sydney in 2016, 37 per cent of NO_X, and 71 per cent of SO_2. Non-exhaust processes, such as brake wear, tyre wear, road surface wear and resuspension of road dust during on-road vehicle usage, were the largest source of road transport PM_{10} (71 per cent) and $PM_{2.5}$ (57 per cent), whereas exhaust emissions from petrol passenger vehicles were only a minor source of road transport PM_{10} (three per cent) and $PM_{2.5}$ (four per cent).

The road transport contribution to CO, volatile organic compounds and NO_X emissions is projected to decrease substantially between 2011 and 2036 due to improvements in emission-control technology. For PM_{10}, $PM_{2.5}$ and SO_2 the road transport contributions are also expected to decrease, but their smaller contributions to these pollutants mean that these decreases would have only a minor impact on total emissions.

12.4.3 Ambient air quality

Air quality in Sydney is monitored across a network of monitoring stations operated by the Department of Planning, Industry and Environment (Environment, Energy and Science), and at project-specific monitoring stations operated by Transport for NSW. A summary of ambient air quality in Sydney is provided in Table 12-6, based on data from these monitoring stations from 2004 to 2019.

Table 12-6 Ambient air quality in Sydney (2004 to 2019)

Air pollutant	Ambient air quality
CO (maximum 1-hour)	All monitoring data shows ambient concentrations well below the air quality criteria of 30 mg/m^3 (1-hour) and 10 mg/m^3 (8-hour). With the exception of 2019, there is a general downward trend in maximum concentrations over time.
CO (rolling 8-hour)	

Air pollutant	Ambient air quality
NO_2 (maximum 1-hour)	Although variable from year to year, maximum 1-hour NO_2 concentrations are relatively stable in the longer term. Data from all monitoring stations typically range from 80 µg/m^3 to 140 µg/m^3, and continue to be well below the criterion of 246 µg/m^3.
NO_2 (annual mean)	Concentrations at all monitoring stations are well below the air quality criterion of 62 µg/m^3. There is a general downward trend in annual mean concentrations over time.
PM_{10} (maximum 24-hour)	Maximum 24-hour mean PM_{10} concentrations show a slight downward until 2015, but there is a large variation from year to year. In 2016 the concentrations recorded at the Transport for NSW monitoring stations were about 40 µg/m^3, below the air quality criterion of 50 µg/m^3. Since 2018, maximum 24-hour PM_{10} concentrations at Department of Planning, Industry and Environment (Environment, Energy and Science) stations exhibited an upward trend due to extended drought conditions and widespread bushfires.
PM_{10} (annual mean)	Concentrations at the Department of Planning, Industry and Environment (Environment, Energy and Science) stations show a downward trend between 2004 and 2016, by as much as 21 to 23 per cent in the case of the Chullora and Earlwood stations. In recent years the annual mean PM_{10} concentration at the Department of Planning, Industry and Environment (Environment, Energy and Science) stations has increased, from around 20 µg/m^3 in 2018 to close to or above the air quality criterion of 25 µg/m^3 in 2019. This is largely due to drought conditions worsening and then severe bushfire activity in 2018 and 2019. The monitoring station at Lindfield shows substantially lower concentrations, about 15 to 16 µg/m^3. Monitoring data from stations operated by Transport for NSW away from busy roads is generally about 15 µg/m^3, which is well below the air quality criterion of 25 µg/m^3.
$PM_{2.5}$ (maximum 24-hour)	There has been no trend in the maximum 24-hour $PM_{2.5}$ concentration. The maximum 24-hour concentrations are often close to or above the air quality criterion of 25 µg/m^3, and were generally above the long-term goal of 20 µg/m^3. Exceedances are largely due to hazard reduction burns and bushfires.
$PM_{2.5}$ (annual mean)	$PM_{2.5}$ has only been measured over several years at three of the Department of Planning, Industry and Environment (Environment, Energy and Science) stations reviewed (ie Chullora, Earlwood and Liverpool). Concentrations show a similar pattern, with a steady reduction between 2004 and 2012 being followed by a substantial increase in 2013. The main reason for the increase was a change in the measurement method. The increases in measured concentrations meant that background $PM_{2.5}$ concentrations between 2013 and 2016 were already very close to or above the air quality criterion of eight µg/m^3, and above the long-term goal of seven µg/m^3. In 2018 and 2019, the annual mean $PM_{2.5}$ concentrations exceeded the air quality criterion at all three monitoring stations.

12.5 Assessment of potential construction impacts

Potential sources of air quality impacts during construction of the project would include:

- Dust generated at construction sites and temporary construction support sites
- Emissions from vehicles, plant and equipment used on construction sites and temporary construction support sites
- Emissions during blasting
- Odour generated during handling and management of harbour sediments and material excavated from the former landfill site at the Flat Rock Drive construction support site (BL2).

Environmental management measures that are proposed to address these impacts are outlined in Section 12.7.

12.5.1 Dust

Overall, dust generated as a result of construction works, with best practice management measures in place, is unlikely to represent a serious ongoing problem. Any effects would be temporary and relatively short-lived and would likely only arise during dry weather where the wind is blowing towards a receiver at a time when dust is being generated and environmental management measures are not fully effective.

Screening assessment

The construction dust assessment considered potential dust impacts across five assessment zones. The assessment zones, and their associated temporary construction support sites and surface construction areas are summarised in Table 12-7. As shown in Figure 12-4, there are a large number of human receivers located within 350 metres, as well as ecological receivers located within 50 metres, of the assessment zones. This has triggered the need for further assessment of potential dust impacts.

Table 12-7 Assessment zones

Assessment zone	Construction support sites within assessment zone	Surface construction areas within assessment zone
Zone 1	Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5), Gore Hill Freeway median (BL6)	Beaches Link and Gore Hill Freeway works. This includes tunnel decline structures and construction of tunnel portals and ramps, construction of operational ancillary infrastructure and adjustments to other infrastructure (eg active transport infrastructure).
Zone 2	Cammeray Golf Course (BL1), Flat Rock Drive (BL2)	Beaches Link tunnel decline structures and tunnel portals at Cammeray Golf Course (BL1) and Flat Rock Drive (BL2), and connections to Warringah Freeway, including fitout of the ventilation outlet and motorway facility. Note: The majority of this construction assessment zone would have already undergone significant disturbance during the construction of the Western Harbour Tunnel and Warringah Freeway Upgrade. The construction activities assessed in this zone therefore assumes that much of the works have already been completed as part of that project.

Assessment zone	Construction support sites within assessment zone	Surface construction areas within assessment zone
Zone 3	Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8), Spit West Reserve (BL9)	Harbour crossing including cofferdam excavation, dredging and handling of dredged material.
Zone 4	Balgowlah Golf Course (BL10), Kitchener Street (BL11)	Connections and integration of Beaches Link to the surrounding road network at Balgowlah. This includes construction of portals and the new access road, modifications to existing surface roads and construction of the Burnt Bridge Creek Deviation ventilation outlet and motorway facility.
Zone 5	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13), Wakehurst Parkway north (BL14)	Connections and integration of Beaches Link with Wakehurst Parkway at Seaforth, Killarney Heights and Frenchs Forest. This includes surface road works associated with the realignment and upgrade of Wakehurst Parkway and minor changes to intersections, as well as the construction of the Wakehurst Parkway motorway facility and ventilation outlet.

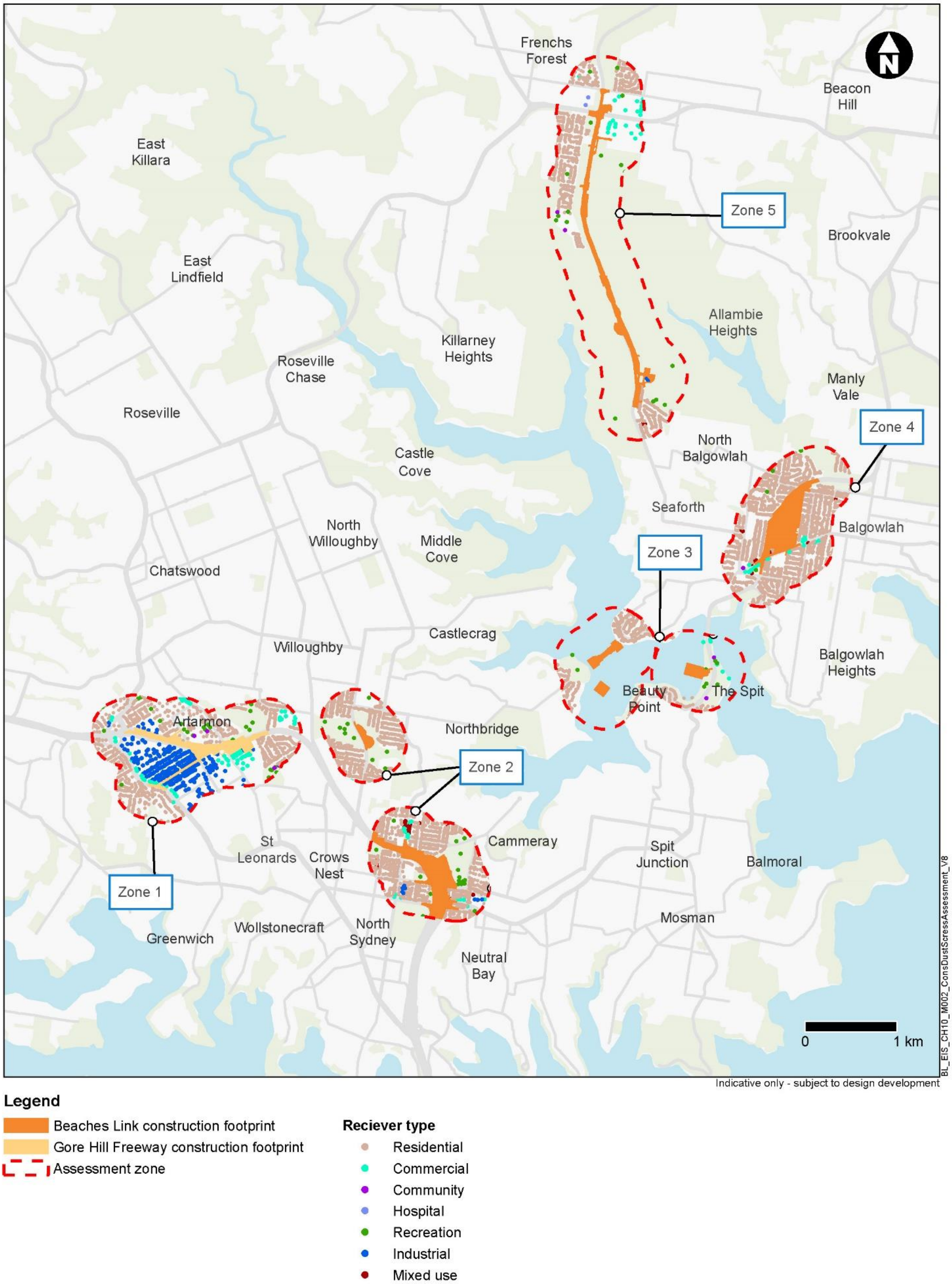

Figure 12-4 Construction dust screening assessment – receivers near the construction footprint

Risk assessment

The risk of potential dust impacts, without mitigation, is determined by combining the following to provide an overall summary of potential risk:

- The scale and nature of the works, which determined the magnitude of potential dust emissions (refer to Table 12-8)
- The sensitivity of the surrounding area to dust settlement effects, human health impacts and ecological impacts (refer to Table 12-9).

Potential for dust emissions from surface construction works

The potential magnitude of dust emissions for the construction works that would be carried out for demolition, earthworks, construction, and track-out (as defined in Section 12.2.2) is shown in Table 12-8, and is based on the scale and nature of the works.

Table 12-8 Potential magnitude of dust emissions of construction works in each assessment zone

Type of activity	Site category by assessment zone				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Demolition	Large	Small	N/A	Medium	Small
Earthworks	Large	Medium	Small	Large	Large
Construction	Large	Medium	Small	Large	Large
Track-out	Large	Medium	Medium	Large	Large

Sensitivity of receivers during construction

The sensitivity of an area to dust settlement effects, human health impacts and ecological impacts during construction takes into account factors such as the number of receivers in the area, the proximity of receivers from construction activities and the local annual mean background PM_{10} concentration. The sensitivity of receivers to dust settlement effects, human health impacts and ecological impacts (without mitigation) within the five surface construction zones assessed is provided in Table 12-9. The results in Table 12-9 show that:

- For construction dust settlement effects:
  - Zone 1, zone 2, zone 4 and zone 5 were considered to have a high sensitivity to dust settlement effects due to the high number of receivers, located near the surface construction works
  - Zone 3 was considered to have a medium sensitivity to dust settlement effects as there were fewer receivers located near construction works. No demolition or track-out dust settlement effects would occur within zone 3.
- For human health impacts,
  - The sensitivity of receivers in zone 1, zone 2, zone 4 and zone 5 would be considered high, due to the high number of receivers located near surface construction works
  - Zone 3 would have a low sensitivity to human health impacts during all construction works. Demolition would not occur in this zone.
- For ecological impacts, sensitive ecological receivers within all the zones are located within 20 metres of the construction disturbance footprint. As a result, the sensitivity of these ecological receivers to construction dust would be considered high at all locations.

Risk of dust impacts

The summary of potential risk relating to construction dust, without mitigation, is provided in Table 12-9.

Without mitigation, sites and works that were determined to have a high and medium risk of dust impacts include:

- Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites: High risk of dust settlement, human health and ecological impacts as a result of demolition, earthworks, construction and track-out activities
- Cammeray Golf Course (BL1) and Flat Rock Drive (BL2) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition, earthworks, construction and track-out activities
- Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve (BL9) construction support sites: Medium risk of ecological impacts and a low risk of dust settlement and human health impacts as a result of track-out activities. Low risk of dust settlement and ecological impacts as a result of earthworks and construction activities
- Balgowlah Golf Course (BL10) and Kitchener Street (BL11) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition activities. High risk of dust settlement, human health and ecological impacts as a result of earthworks, construction and track-out activities
- Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition activities. High risk of dust settlement, human health and ecological impacts as a result of earthworks, construction and track-out activities.

The effects of airborne dust during construction works would likely be temporary and of relatively short duration. For all construction works, the aim would be to prevent dust related impacts on receivers, through the implementation of best management practices routinely used on construction sites. The proposed environmental management measures are outlined in Section 12.7 and would include measures such as:

- Suppressing dust with water
- Covering stockpiles of loose materials
- Cleaning up loose materials from hard surfaces
- Stabilising unsealed areas
- Selection of equipment and materials handling techniques that minimise the potential for dust generation
- Ceasing dust generating activities during unfavourable weather conditions or changing how they are managed to minimise dust emission
- Site inspections and activity supervision to monitor the effectiveness of implemented measures and identify any additional measures to be implemented.

However, even with rigorous air quality management in place and the effective best practice management measures described above, there is the risk that nearby residences, commercial premises and schools near construction works might experience occasional dust impacts. This does not imply that impacts are likely, or that if they did occur, that they would be frequent or persistent. Overall dust generated as a result of construction works is unlikely to represent a serious ongoing problem.

Table 12-9 Summary of potential risk relating to construction dust (without mitigation)

Zone	Activity	Step 2A: Potential for dust emissions	Step 2B: Sensitivity of area			Step 2C: Risk of dust impacts		
			Dust settlement	Human health	Ecological	Dust settlement	Human health	Ecological
Zone 1 (BL3, BL4, BL5 and BL6)	Demolition	Large	High	High	High	High	High	High
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High
Zone 2 (BL1, BL2)	Demolition	Small	High	High	High	Medium	Medium	Medium
	Earthworks	Medium	High	High	High	Medium	Medium	Medium
	Construction	Medium	High	High	High	Medium	Medium	Medium
	Track-out	Medium	High	High	High	Medium	Medium	Medium
Zone 3 (BL7, BL8 and BL9)	Demolition	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Earthworks	Small	Medium	Low	High	Low	Negligible	Low
	Construction	Small	Medium	Low	High	Low	Negligible	Low
	Track-out	Medium	Low	Low	High	Low	Low	Medium
Zone 4 (BL10 and BL11)	Demolition	Medium	High	High	High	Medium	Medium	Medium
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High
Zone 5 (BL12, BL13 and BL14)	Demolition	Small	High	High	High	Medium	Medium	Medium
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High

Dust emissions containing contaminants

There is the potential for dust emissions to contain contaminants mobilised through the disturbance of contaminated soils, and other hazardous materials (such as asbestos fibres or organic matter) during demolition of buildings and other structures. These issues would be considered on a site-by-site basis and would be effectively managed through standard air quality mitigation and management measures as outlined in Table 12-11.

Areas identified as potentially containing contaminated soils and other hazardous substances, which may be disturbed during construction, include:

- Warringah Freeway, North Sydney to Cammeray
- Punch Street, Artarmon
- Freeway Hotel, Artarmon
- Flat Rock Reserve, Northbridge
- Spit West Reserve, Mosman
- Balgowlah Golf Course, Balgowlah
- Dudley Street, Balgowlah
- Judith Street and Kirkwood Street, Seaforth
- Sydney Water Bantry Bay Reservoir site, Killarney Heights
- Burnt Bridge Creek Deviation, Balgowlah
- Wakehurst Parkway, Seaforth to Frenchs Forest.

These areas are described in more detail in Chapter 16 (Geology, soils and groundwater). These areas would be investigated further in accordance with requirements of guidance endorsed under Section 105 of the *Contaminated Land Management Act 2008* to confirm the contamination present, and the implementation of Remedial Action Plans prepared in accordance with *Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land* (Department of Urban Affairs and Planning and Environment Protection Authority, 1998). Remedial Action Plans consider all potential risk pathways for exposure to contaminants and specify the controls required to reduce those risks to acceptable levels. This includes potential emissions of contaminated dust. Refer to Chapter 16 (Geology, soils and groundwater) for more details.

12.5.2 Emissions from vehicles, plant and equipment

The use of on-site diesel-powered vehicles, generators and construction equipment, and the handling and/or on-site storage of fuel and other chemicals, would result localised increased concentrations of airborne particle matter, CO, NO_X, sulfur dioxide and volatile organic compounds. Minor emissions from these sources would be localised and would be managed with standard environmental management measures.

12.5.3 Emissions during blasting

As discussed in Chapter 6 (Construction work), it is anticipated that controlled blasting might be used to excavate bedrock along sections of Wakehurst Parkway, as an alternative to ripping or hammering of rock, to minimise the duration of this activity and potential noise and amenity impacts. In addition, controlled blasting may also be carried out during construction of the driven tunnels.

Controlled underground blasting would not result in direct emissions to the external air. The potential for impacts to sensitive receivers due to dust from surface-based blasting would depend on the location where the blasting is proposed, the blasting approach, and whether there are any sensitive receivers in the vicinity that could be impacted. Emissions to air from any blasting required at Wakehurst Parkway would be managed to ensure safe working conditions for workers and minimise potential impacts to sensitive receivers in the vicinity.

12.5.4 Odour

This section assesses impacts associated with potential odours due to dredging activities, stockpiling and transport of dredged material at Middle Harbour, as well as excavation activities within a former landfill site at the Flat Rock Drive construction support site (BL2).

Environmental management measures such as odour supressing additives, use of sealed trucks and the development of an odour management strategy (where required) would be implemented to minimise the potential for odour during construction.

Excavated material from Middle Harbour

As part of the tunnelling activities for the project, a significant amount of material would be excavated from beneath the water. This would be done using mechanical dredging, bringing potentially odorous material to the surface. While on the barges in the vicinity of the dredging activity or while in transit to the sea disposal location or onshore disposal area, dredged material would be covered with water which would significantly reduce any odour emissions. Any odour impacts from this material would be negligible to low, given it would remain wet and located at some distance from any sensitive receiver.

For dredged material that is determined to be unsuitable for sea disposal, the material would be transported by barge to land, made spadable and then transported by truck to an appropriately licensed waste management facility for disposal. The unloading location for the dredged material would be determined during detailed design, and necessary environmental planning approvals obtained to operate the facility to accept and, if required, treat the material. Odour measurements carried out on dredged material from Middle Harbour showed extremely low concentrations. Modelling for the same material for the Western Harbour Tunnel air quality assessment showed if handled in manageable quantities, it is unlikely that emissions from dredged material would result in detectable levels of odour at any sensitive receivers.

Excavation at Flat Rock Drive construction support site (BL2)

The Flat Rock Drive construction support site (BL2) is a tunnel support site and would have an access decline to the tunnels underground.

The area to the west of Flat Rock Drive and east of Willoughby Road at Willoughby was used extensively as a municipal landfill prior to redevelopment as recreation facilities. Following the construction of Flat Rock Drive in 1968, and prior to 1971, areas to the east of the road were filled with material comprising of putrescible waste. Since that time the majority of fill has been non-putrescible, predominantly consisting of building debris and so the material most likely to be encountered during excavation in this area would the more recent non-putrescible waste. A geotechnical investigation carried out within the construction footprint at this location identified clayey material with some building debris but did not encounter any putrescible waste.

There is some potential that landfill gases might be present in the soils underneath the Flat Rock Drive construction support site (BL2) from any putrescible waste present, or that might have migrated from the landfilled areas to the west.

To manage the potential risks associated with the historic use of the area, the Flat Rock Drive construction support site (BL2) has been designed to minimise excavations. The main excavations that would be required are associated with piling for structures and excavation of the tunnel access decline. The location of the decline has been chosen to minimise the amount of excavation required to reach bedrock. As such, there is limited potential to encounter putrescible landfilled waste (if present) that could generate odour. Additionally, the potential for the release of significant volumes of landfill gases (if present) is also limited.

As there is a low potential for significant amounts of putrescible waste materials and landfill gases to be present beneath the proposed Flat Rock Drive construction support site (BL2) site, the potential for significant odour issues during excavation is very low. However, prior to excavations at the temporary construction support site, further investigations would be carried out to confirm the potential to encounter odorous materials and gases and need for any site-specific management measures (refer to environmental management measures SG14 in Chapter 16 (Geology, soils and groundwater) and AQ4 in Section 12.7.1).

12.6 Assessment of potential operational impacts

Key areas of consideration with regards to air quality impacts during the operation of the project would include:

- In-tunnel air quality, including protection of amenity and motorist health when using the project tunnels and during longer trips through other parts of the motorway network
- Ambient air quality for receivers at ground level, as a result of changes in the distribution of surface traffic and operation of the project's ventilation facilities
- Ambient air quality for elevated receivers in existing and potential future high rise buildings, as a result of operation of the project's ventilation facilities
- Odour caused by odorous compounds in vehicle emissions.

12.6.1 In-tunnel air quality

The project's ventilation systems have been designed to achieve the in-tunnel air quality criteria summarised in Section 12.3.2 under all traffic conditions, and to effectively manage smoke in the event of a fire in the project tunnels. The tunnel ventilation system would include:

- Jet fans installed in the ceiling of the tunnels
- Axial fans within the motorway facilities to extract air from the tunnel via ventilation tunnels
- Axial fans within the motorway facilities to supply air to the tunnel via ventilation tunnels
- Ventilation outlets to effectively disperse tunnel air into the atmosphere
- Air quality monitoring systems in the tunnels and ventilation outlets to monitor and control the ventilation system.

The design and operation of the tunnel ventilation system is shown in Figure 5-1 of Chapter 5 (Project description) and described in Section 5.2.7 of that chapter and Appendix H (Technical working paper: Air quality).

The design of the tunnel ventilation system would ensure there would be no emissions from the tunnel portals. This would involve using jet fans close to the exit portals to draw air back into the tunnel, to be emitted via the ventilation outlets.

Simulations have been carried out to demonstrate that in-tunnel air quality criteria would not be exceeded. The simulations consider in-tunnel air quality based on:

- Expected traffic volumes using the project tunnels
- Maximum traffic volumes based on the design capacity of the tunnels at different average traffic speeds
- Congestion due to a breakdown or incident in the project tunnels.

In-tunnel air quality under expected traffic conditions

The change in the peak in-tunnel NO_2 (rolling 15-minute average) emissions throughout the project tunnel and the adjoining tunnels confirm that the tunnel ventilation system would maintain in-tunnel air quality well within operational limits. The predicted in-tunnel NO_2 levels modelled for all 'Do something' and 'Do something cumulative' scenarios in 2027 and 2037 are provided in Section 7 of

Annexure K of Appendix H (Technical working paper: Air quality). The in-tunnel operational air quality limits for CO and visibility would also be achieved under all expected traffic scenarios.

In-tunnel air quality under worst case variable speed operation

In-tunnel air quality was assessed with the mainline tunnels operating at theoretical maximum lane capacity over the full length of the tunnels (which is not expected to actually occur). Four variable speed scenarios were assessed along all northbound and southbound routes: 20 kilometres per hour, 40 kilometres per hour, 60 kilometres per hour and 80 kilometres per hour. Vehicles travelling at 20 kilometres per hour are predicted to result in the highest pollutant levels in the tunnel, due to less air moving through the tunnel. This is considered the worst case variable speed operation scenario.

The predicted in-tunnel NO_2 (rolling 15-minute average) emissions for the worst case northbound route through the tunnel confirms that the tunnel ventilation system would achieve the NO_2 emissions criteria during all variable speed operation scenarios. The in-tunnel operational air quality limits for CO and visibility would also be achieved during all variable speed operation scenarios (refer to Annexure K of Appendix H (Technical working paper: Air quality)).

In-tunnel air quality under worst case breakdown or major incident

The tunnel ventilation system would be designed to cater for various traffic scenarios, including a case where there is a breakdown or major incident at a point along the tunnel. The worst case scenario from a traffic perspective would be where the resulting congestion due to a breakdown affects the longest length within the tunnel operating at capacity. The assessment considered breakdowns in a range of plausible locations.

The highest trip average NO_2 concentration for the breakdown scenarios considered was 0.29 ppm. This was predicted during a breakdown or major incident along the route for traffic originating in Killarney Heights and Balgowlah and exiting at the Warringah Freeway exit ramp (prior to the Western Harbour Tunnel). The predicted in-tunnel trip average NO_2 concentration for the worst case vehicle breakdown or major incident scenario in the tunnel confirms that the tunnel ventilation system would achieve the NO_2 emissions criteria during all breakdown scenarios. The in-tunnel operational air quality limits for NO_2, CO and visibility would also be achieved during all breakdown or major incident scenarios (refer to Annexure K of Appendix H (Technical working paper: Air quality)).

In-tunnel air quality for extended journeys

The extended journey assessment considered the longest potential journey that could be taken by motorists in the connected motorway network in 2037. This was identified as a journey that used the project, the proposed Western Harbour Tunnel, WestConnex and the M6 Motorway (Stage 1) tunnel network. It is expected that the in-tunnel trip average NO_2 concentrations would remain below the 0.5 ppm criterion under all traffic conditions, provided that NO_2 emissions criteria are achieved in every tunnel (which is expected). Further detail can be found in Section 5.2.7 of Annexure K of Appendix H (Technical working paper: Air quality).

12.6.2 Ambient air quality (receivers at ground level)

The predicted ambient air quality for the expected traffic scenarios are presented, by pollutant in this section. All results, including tabulated concentrations and contour plots are provided in Appendix H (Technical working paper: Air quality).

For the pollutants assessed, the following has been determined for over 35,000 residential, workplace and recreational receiver locations and 42 community receivers:

- The total ground-level concentrations for comparison against the NSW impact assessment criteria and international air quality standards

- The change in the total ground-level concentrations. This was calculated as the difference in concentration between the 'Do something' and 'Do minimum' scenarios, ie the difference in ground-level concentrations as a result of the project
- The contributions of the background, surface road and ventilation outlet sources to the total ground-level concentrations.

Due to the number of residential, workplace and recreational receiver locations, ranked plots for pollutant concentrations at each receiver location have been included. In each figure the background concentration, maximum contributions from each source (ventilation outlets and surface roads) and the maximum total concentration have been included for all the 'Do something' and 'Do something cumulative' scenarios.

For community receivers, a figure showing the pollutant concentrations (background plus the project scenario contribution) at each receiver relative to the air quality criterion has been provided. A second figure showing the change in pollutant concentration as a result of the different project scenario contributions at each receiver has also been provided.

Nitrogen dioxide (maximum 1-hour mean)

Residential, workplace and recreational receiver locations

There are some predicted exceedances of the NSW 1-hour NO_2 criterion (246 µg/m^3), both with and without the project at residential, workplace and recreational receiver locations. In the 'Do minimum 2027' scenario, the maximum concentration of NO_2 exceeds the NSW criterion at 201 receivers (0.6 per cent of all receivers). With the introduction of the project in the 'Do something 2027' scenario, the number of receivers experiencing exceedances of the maximum concentration of NO_2 decreases to 153 receivers. In the 'Do something cumulative 2027' scenario, the number of receivers experiencing exceedances of the maximum 1-hour mean concentration of NO_2 further decreases to 88 receivers (0.2 per cent of all receivers).

In the 'Do minimum 2037' scenario, there are predicted to be exceedances at 234 receivers (0.7 per cent of all receivers), and this remained the same for the 'Do something 2037' scenario. In the 'Do something cumulative 2037' scenario, the number decreases to 75 receivers (0.2 per cent of all receivers).

Most exceedances in all scenarios were located along Warringah Freeway (and the Warringah Freeway Upgrade) in future years. There were also a small number of exceedances close to Victoria Road in Rozelle and along Manly Road at The Spit. These exceedances reduced even further in the cumulative scenarios when the Western Harbour Tunnel is introduced.

Figure 12-5 shows the predicted contributions of the project to the maximum 1-hour mean NO_2 concentration at all of the residential, workplace and recreational receiver locations.

The maximum contribution of ventilation outlets to NO_2 at any receiver was 60 µg/m^3 in the 'Do something cumulative 2037' scenario. Since this contribution would not coincide with maximum contributions from surface roads, this would not lead to an exceedance of the 1-hour NO_2 criterion.

Community receivers

Figure 12-6 shows the maximum 1-hour NO_2 concentrations at all the community receivers in the project and cumulative scenarios. At all these receiver locations in all scenarios assessed, the maximum concentration is predicted to be below the impact assessment criterion of 246 µg/m^3, and in most cases below 200 µg/m^3.

Figure 12-7 shows the predicted change in maximum 1-hour mean NO_2 concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. There was a mixture of small (relative to the NSW criterion) increases and decreases across the scenarios assessed and some notable increases in the maximum concentration at a small number of receivers, but as noted above, these did not result in any exceedances of the criterion.

In the hour in which the maximum 1-hour NO_2 concentration occurred, the background concentration was the most important source of NO_2, with generally a small contribution from surface roads. The main exceptions were CR06 (St Aloysius College, Milsons Point) and CR11 (Neutral Bay Public School, Neutral Bay), which had a large contribution from surface roads in the 'Do something' scenario and the 'Do something cumulative' scenario respectively. The tunnel ventilation outlet contribution to the maximum 1-hour mean NO_2 concentration was either zero or negligible.

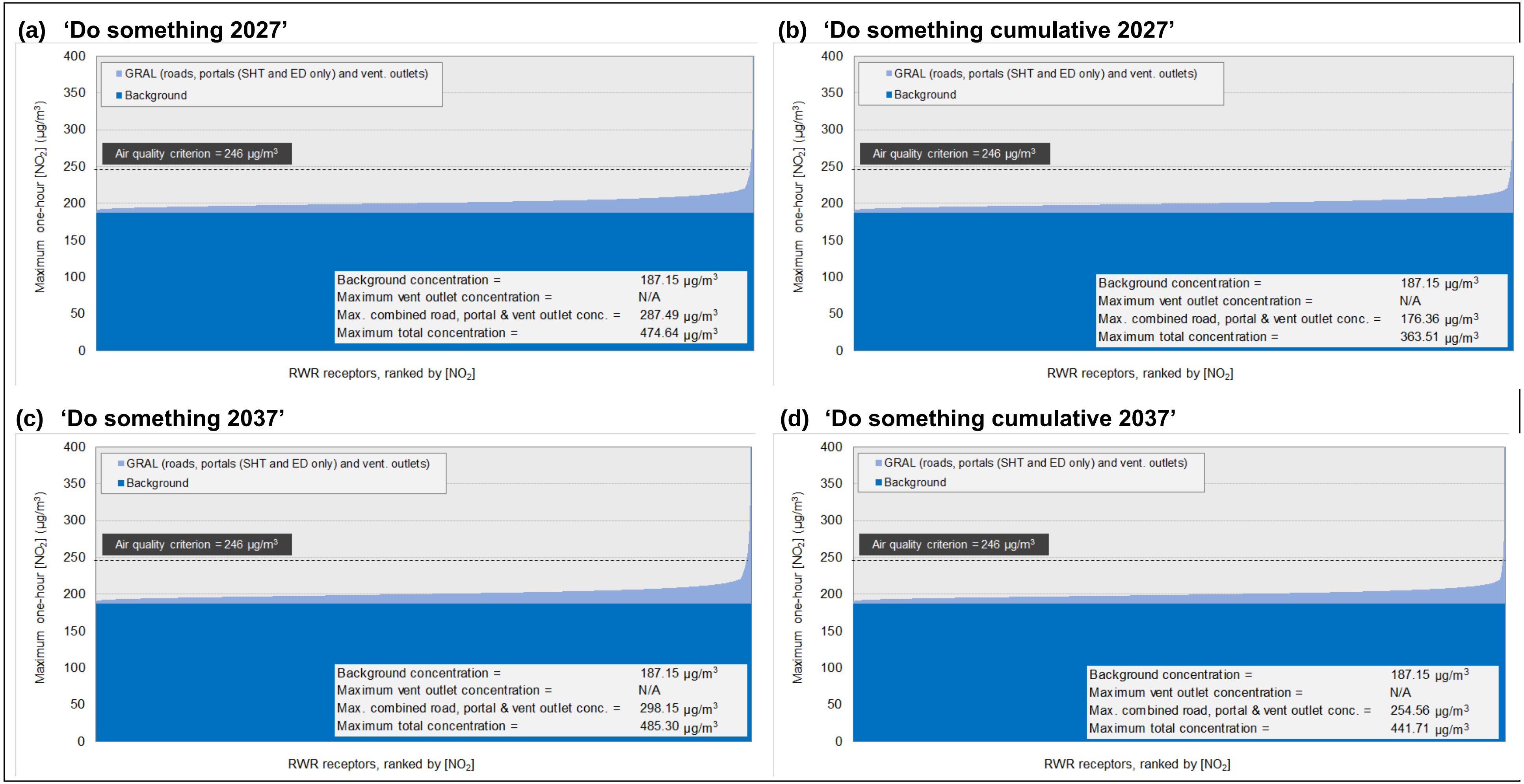

Figure 12-5 Contributions to maximum 1-hour mean NO_2 concentration at residential, workplace and recreational receivers

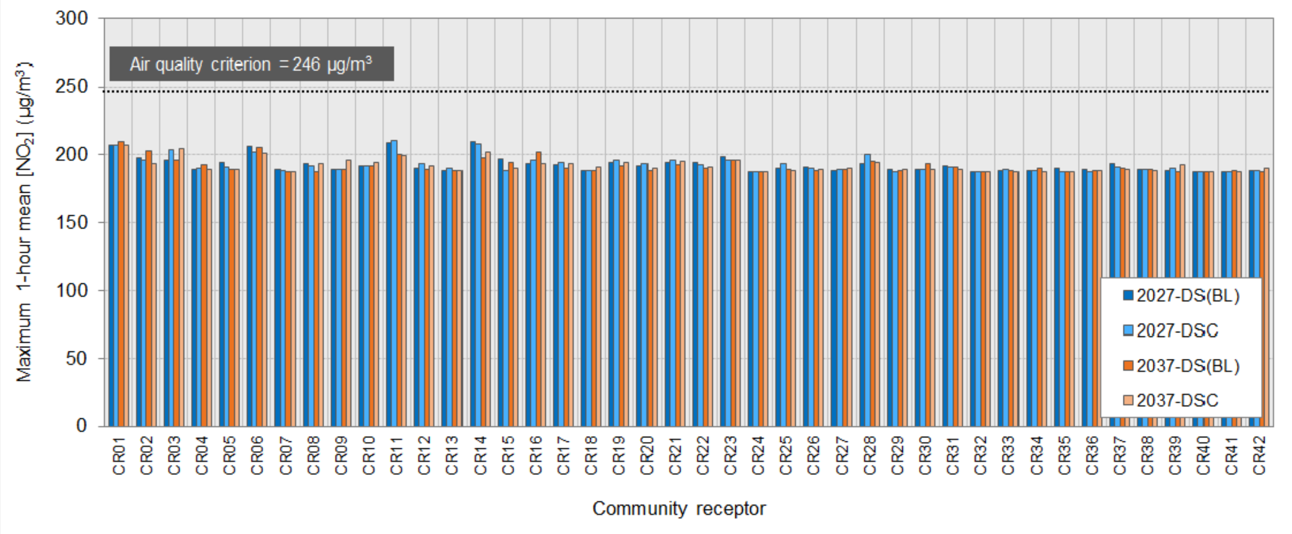

Figure 12-6 Maximum 1-hour mean NO_2 concentration at community receivers

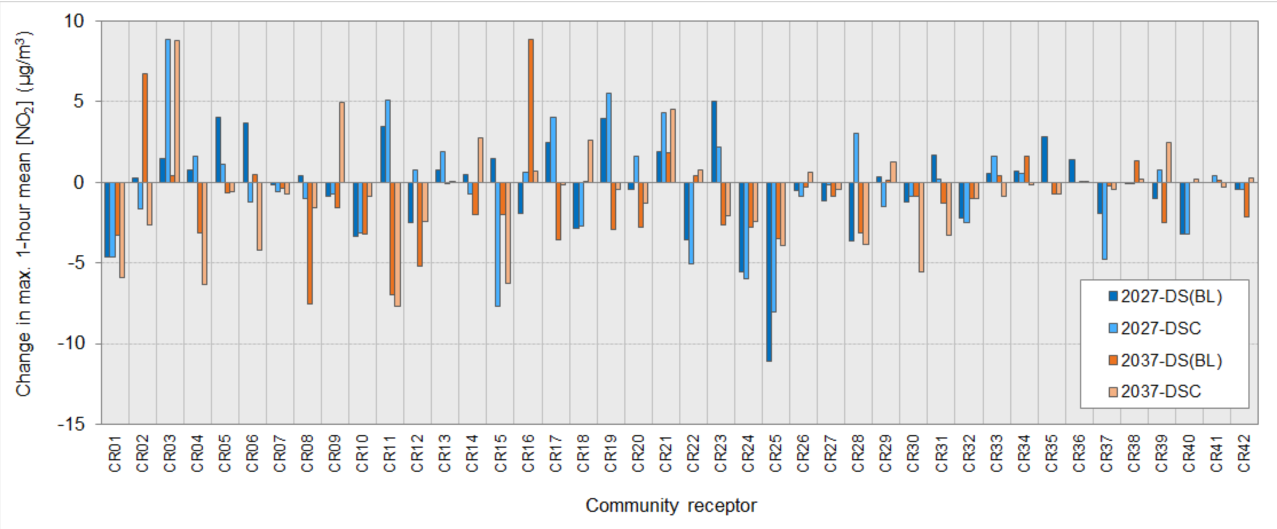

Figure 12-7 Change in maximum 1-hour mean NO_2 concentration at community receivers

Nitrogen dioxide (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-8 shows the predicted contribution of the 'Do something' and 'Do something cumulative' scenarios to annual mean NO_2 concentration at residential, workplace and recreational receiver locations. The predicted annual mean NO_2 concentrations at most (more than 97 per cent) of the receiver locations are between about 13 µg/m^3 and 25 µg/m^3. The annual mean NO_2 criterion of 62 µg/m^3 would not be exceeded at any receiver locations under all scenarios assessed.

The maximum predicted NO_2 contribution at ground level from the ventilation outlets would be 0.7 µg/m^3, and the maximum predicted surface road contribution would be 24.3 µg/m^3, under all scenarios assessed. Given that annual mean NO_2 concentrations at most receiver locations would be well below the criterion, the contribution of the ventilation outlets at ground level is considered negligible.

Community receivers

Figure 12-9 shows the predicted annual mean NO_2 concentrations for the project and cumulative scenarios at community receivers. At all these locations the concentration is predicted to be below 40 µg/m^3, and well below the annual mean NO_2 criterion of 62 µg/m^3 for all scenarios assessed.

Figure 12-10 shows the predicted change in annual mean NO_2 concentration at all of the community receivers. There is a small predicted increase (<2 µg/m^3) in the NO_2 concentration at some community receivers. The largest increase with the project under the scenarios assessed would be about 1.3 µg/m^3 in the 2037 'Do something' scenario, equating to less than three per cent of the criterion. There would also be some notable decreases in the annual mean NO_2 concentration at some receivers (in North Sydney, Mosman and Seaforth) in both the 'Do something' and 'Do something cumulative' scenarios in 2027 and 2037.

For the scenarios assessed, the background component at the community receivers is likely to be responsible for, on average, about 80 to 90 per cent of the predicted total annual mean NO_2, with most of the remainder being due to surface roads. At most receivers, surface roads would contribute between 10 and 30 per cent of the total annual mean NO_2 concentration. The contributions of tunnel ventilation outlets were less than three per cent in all scenarios.

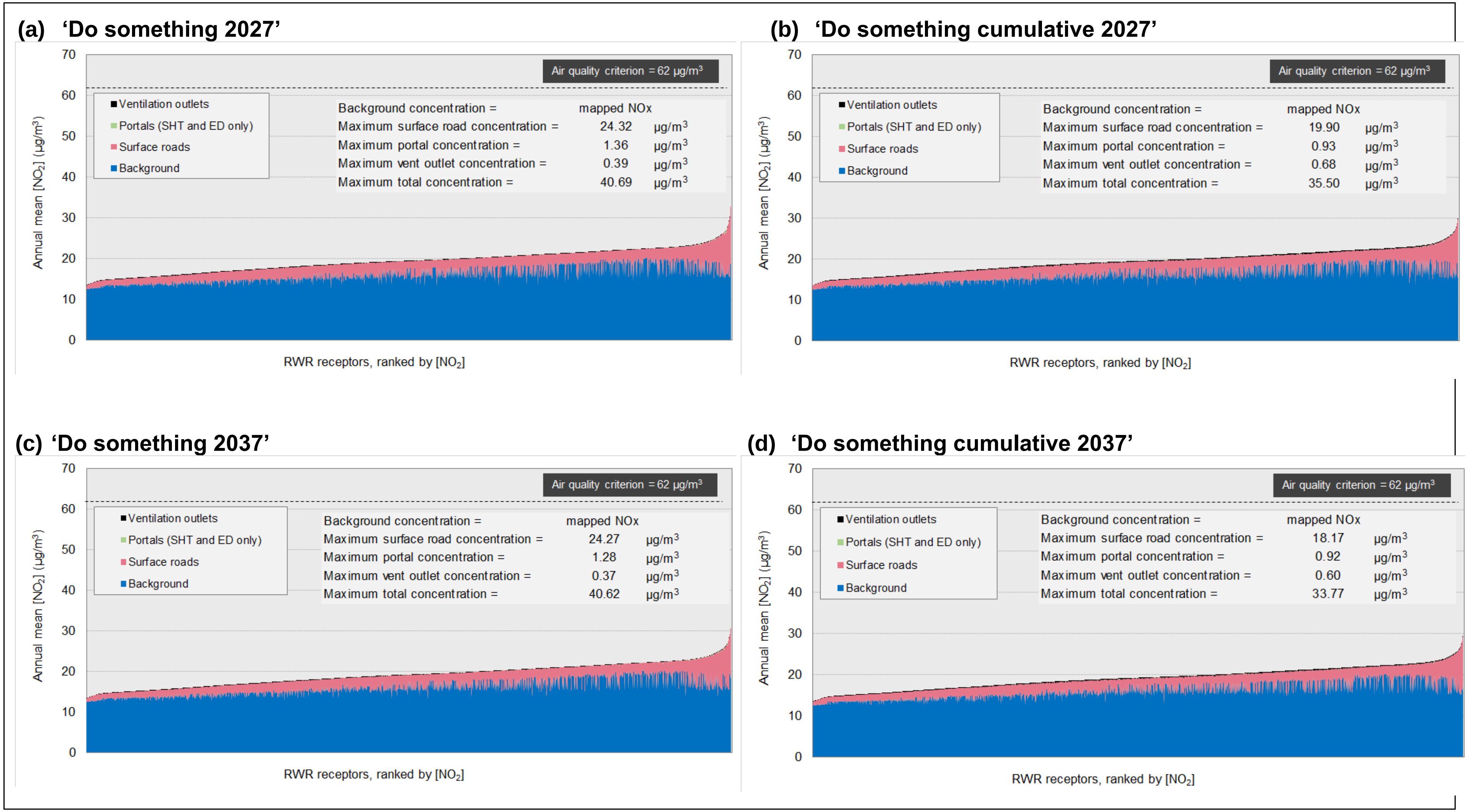

Figure 12-8 Contributions to annual mean NO_2 concentration at residential, workplace and recreational receivers

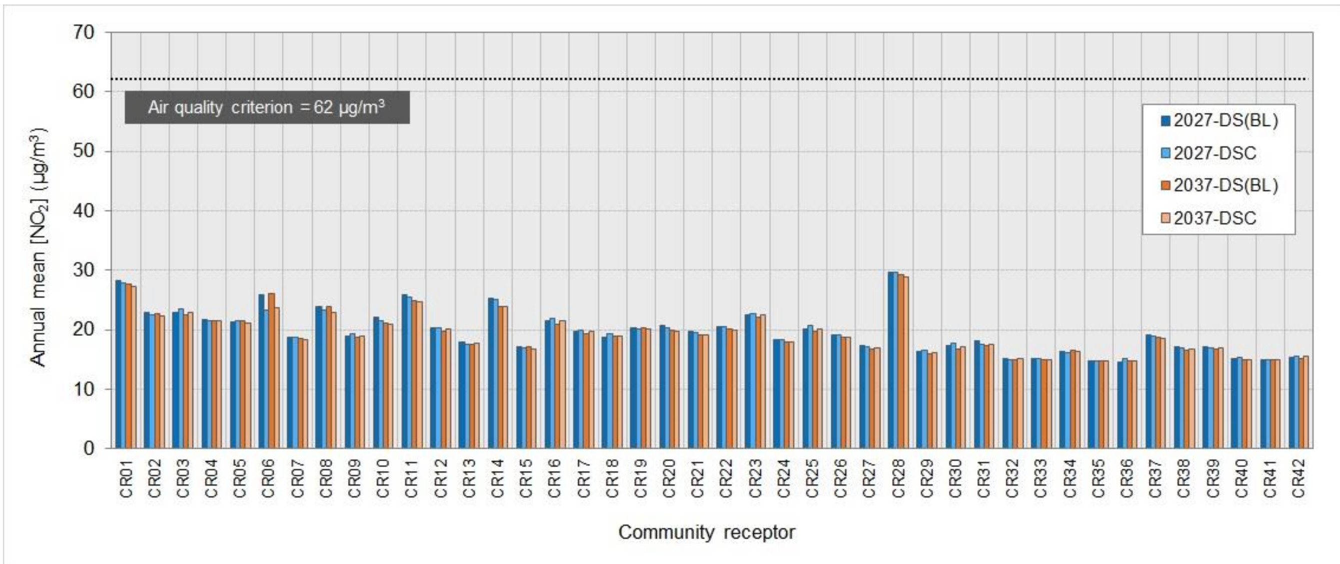

Figure 12-9 Annual mean NO_2 concentration at community receivers

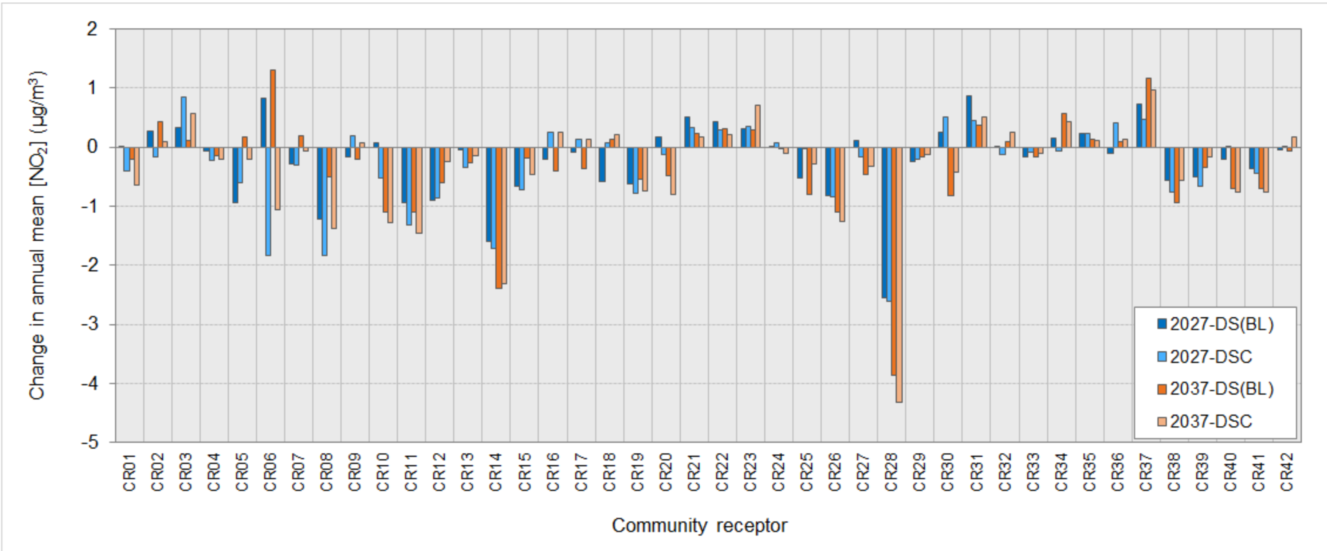

Figure 12-10 Change in annual mean NO_2 concentration at community receivers

PM_{10} (maximum 24-hour mean)

Residential, workplace and recreational receiver locations

Figure 12-11 shows predicted contributions of the project to maximum 24-hour mean PM_{10} concentrations at all the residential, workplace and recreational receiver locations. The results are highly dependent on the assumption for the background concentration (48.04 µg/m^3), which is driven by extreme events such as dust storms, bushfires and hazard reduction burns that occurred in 2016. Accordingly many of the receivers in the 'Do something' and 'Do something cumulative' scenarios (around 63 per cent) are predicted to be above the criterion of 50 µg/m^3. For the 'Do something' and 'Do something cumulative' scenarios, the maximum predicted contribution at ground level from the project's tunnel ventilation outlets at any receiver location would be between 0.7 µg/m^3 and 1.8 µg/m^3.

The largest predicted increase in concentration at any receiver as a result of the project was 6.1 µg/m^3, and the largest predicted decrease was 9.8 µg/m^3. The number of receivers for which a concentration above the criterion is predicted to reduce as a result of the project are as follows:

- From 23,065 in the 'Do minimum 2027' scenario to 21,795 in the 'Do something 2027' scenario and to 21,083 in the 'Do something cumulative 2027' scenario
- From 24,341 in the 'Do minimum 2037' scenario to, 23,236 in the 'Do something 2037' scenario and 22,507 in the 'Do something cumulative 2037' scenario.

Community receivers

Figure 12-12 shows the predicted maximum 24-hour mean PM_{10} concentrations at all of the community receivers in the project and cumulative scenarios. The predicted maximum 24-hour mean PM_{10} concentration is predicted to exceed the criterion of 50 µg/m^3 under all modelled scenarios, due to elevated background concentrations which occur during extreme events such as dust storms, bushfires and hazard reduction burns.

The background concentration is the largest contributor to predicted peak 24-hour PM_{10} concentrations under all modelled scenarios. For the majority of community receivers, the maximum total 24-hour concentration occurred on one day of the year, which coincided with the highest 24-hour background concentration in the PM_{10} profile (126.2 µg/m^3), recorded during a hazard reduction burn. The predicted surface road contribution to the maximum 24-hour PM_{10} concentration at each community receiver is relatively small (less than 4.2 µg/m^3). In the 'Do something' scenarios (ie with the operation of the project), the ventilation outlet contributions at all community receivers were less than 0.3 µg/m^3.

Figure 12-13 shows the predicted change in maximum 24-hour mean PM_{10} concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. The changes were variable and there was no systematic changes by year or by scenario. At several receivers, there would be a predicted increase in concentration, but this would be less than about one µg/m^3.

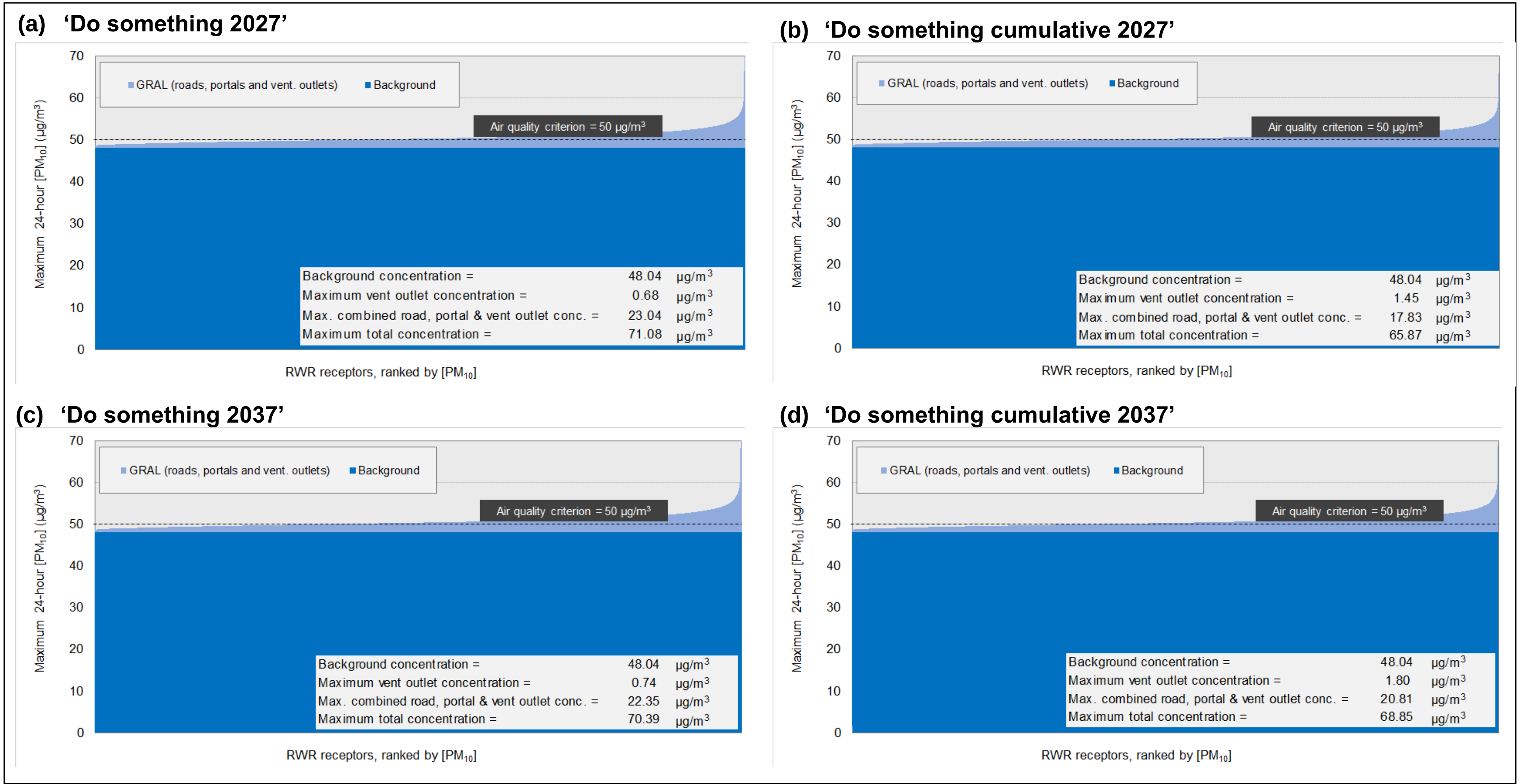

Figure 12-11 Contributions to maximum 24-hour mean PM_{10} concentration at residential, workplace and recreational receivers

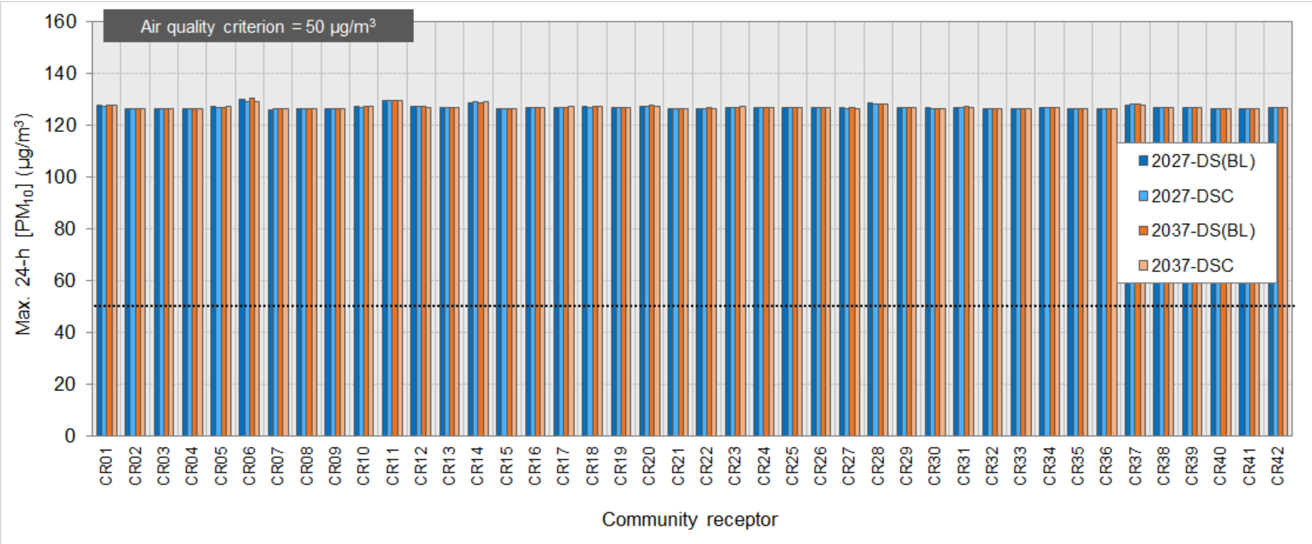

Figure 12-12 Maximum 24-hour mean PM_{10} concentration at community receivers

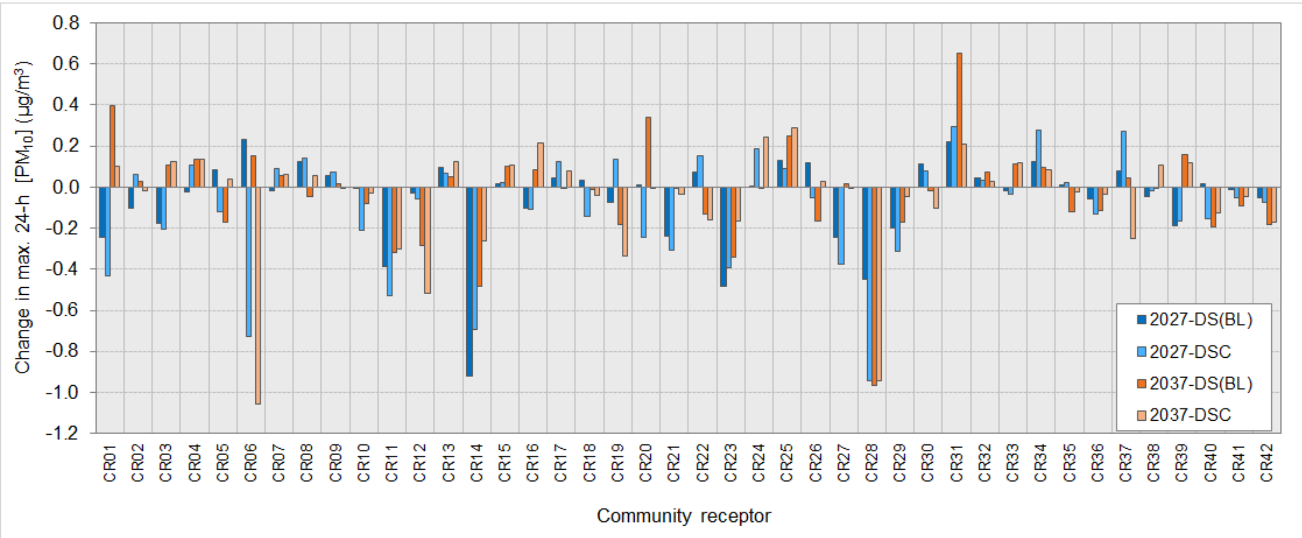

Figure 12-13 Change in maximum 24-hour mean PM_{10} concentration at community receivers

PM_{10} (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-14 shows the 'Do something' and 'Do something cumulative' scenarios predicted contributions to the annual mean PM_{10} concentration at all the residential, workplace and recreational receiver locations. It demonstrates that the concentration at most receivers is predicted to be below 20 µg/m^3, and only one receiver is predicted to have a concentration above the criterion of 25 µg/m^3 under all scenarios assessed. The receiver is a commercial property (the control centre for Sydney Harbour Tunnel), located in the middle of the Bradfield Highway. This receiver had exceedances in the 'Do minimum' and 'Do something' scenarios.

An increase in annual mean PM_{10} concentration is predicted at less than half of receivers (between around 39 per cent and 45 per cent of receivers), with the increase considered to be negligible at the majority of receivers. The largest predicted surface road contribution was about 10.7 µg/m^3, with an average about 0.8 to 0.9 µg/m^3. The largest predicted contribution at ground level from the project's ventilation outlets would be 0.3 µg/m^3 in the 'Do something cumulative 2037' scenario.

Community receivers

Figure 12-15 shows the predicted annual mean PM_{10} concentrations at all the community receivers in the project and cumulative scenarios. PM_{10} concentrations are predicted to be below the criterion of 25 µg/m^3 at all receivers in all scenarios.

Figure 12-16 shows the predicted changes in annual mean PM_{10} concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' and 'Do something cumulative' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. The largest predicted increase would be about 0.5 µg/m^3 (two per cent of the criterion) at receiver CR03 (St Basil's, Annandale), and the largest decrease would be 1.5 µg/m^3 at receiver CR28 (Peek A Boo Cottage, Seaforth).

Annual mean PM_{10} concentrations in the 'Do something' and 'Do something cumulative' scenarios for 2027 and 2037 would be dominated by existing PM_{10} concentrations (background). The predicted contribution from surface roads at most receivers would be small (up to three µg/m^3) and the contribution from the project's ventilation outlets would be negligible (less than about 0.2 µg/m^3).

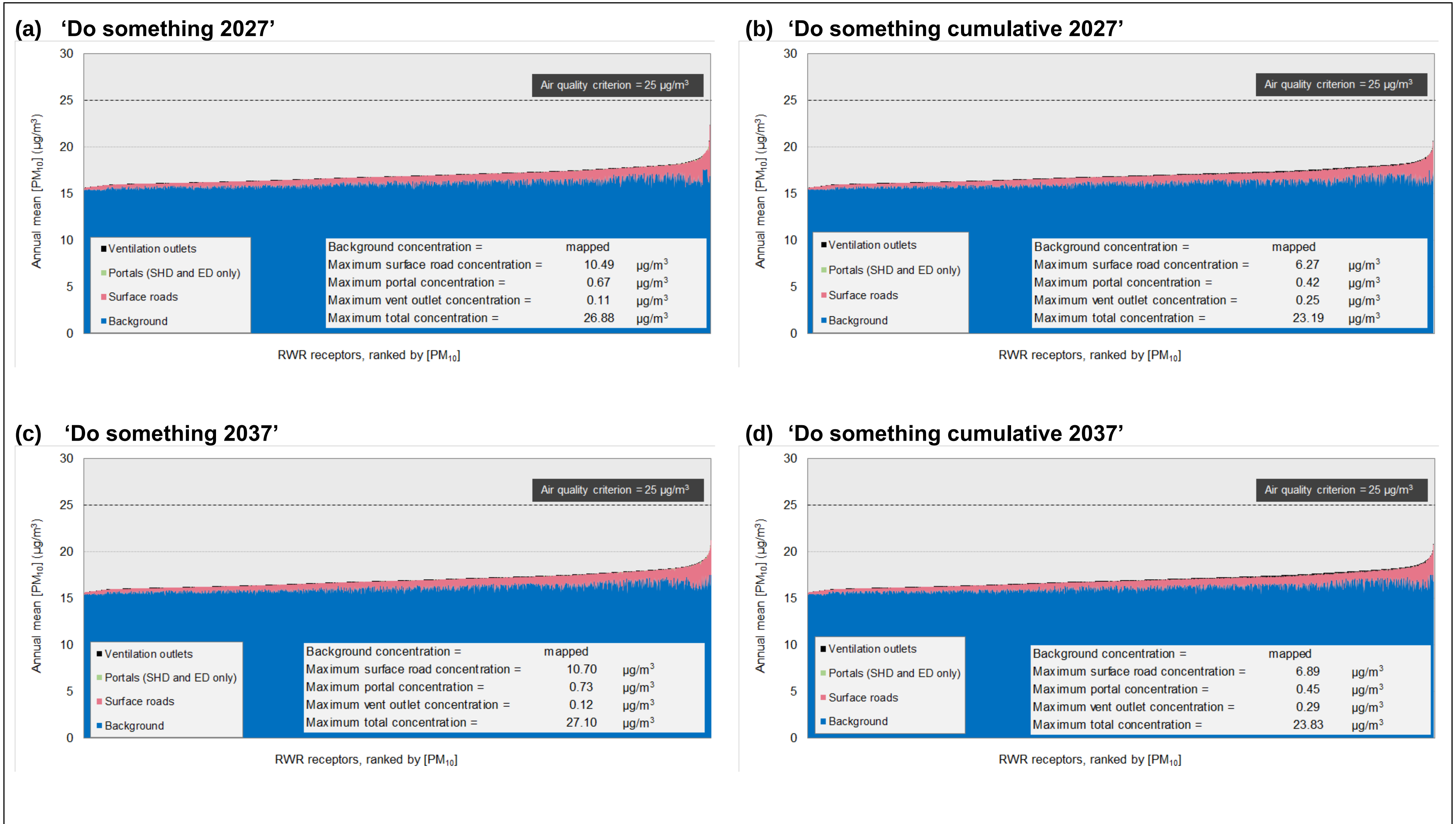

Figure 12-14 Contributions to annual mean PM_{10} concentration at residential, workplace and recreational receivers

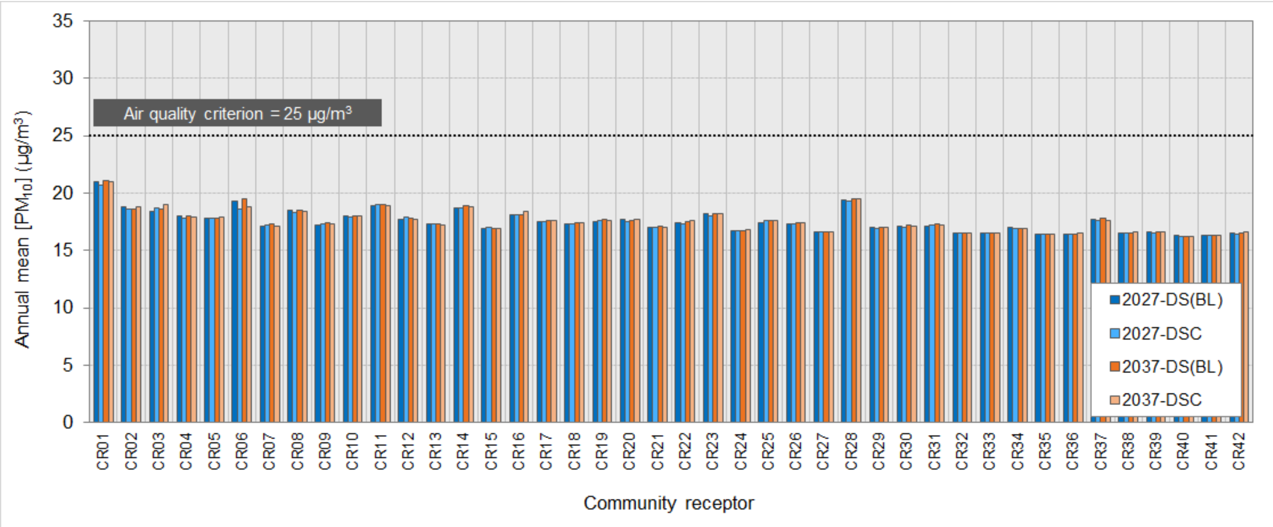

Figure 12-15 Annual mean PM_{10} concentration at community receivers

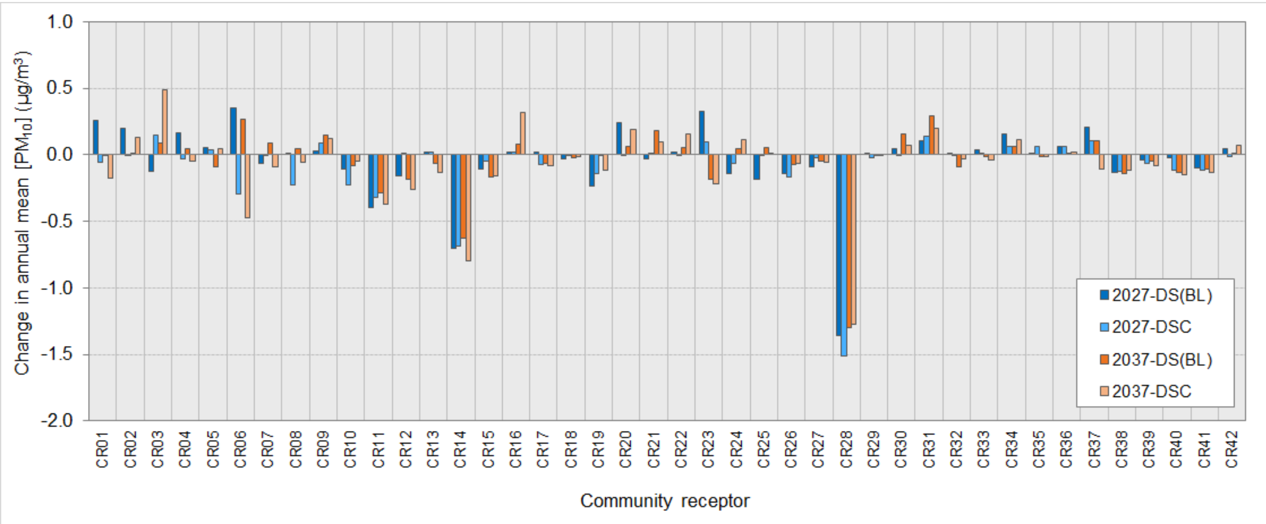

Figure 12-16 Change in annual mean PM_{10} concentration at community receivers

$PM_{2.5}$ (maximum 24-hour mean)

Residential, workplace and recreational receiver locations

Figure 12-17 shows predicted contributions of the project to the maximum 24-hour mean $PM_{2.5}$ concentration at all of the residential, workplace and recreational receiver locations. The main contributor to the predicted maximum 24-hour mean $PM_{2.5}$ concentration was elevated background concentrations that occur during extreme events such as dust storms, bushfires and hazard reduction burns. Consequently, the predicted maximum 24-hour mean $PM_{2.5}$ concentration at a large proportion of receivers was above the criterion of 25 µg/m^3, although this decreased slightly with the project. The proportion of exceedances decreased from 8.6 per cent in the ‘Do minimum 2027’ scenario to 7.1 per cent in the ‘Do something 2027’ scenario and 5.9 per cent in the ‘Do something cumulative 2027’ scenario. The proportion of exceedances are slightly higher in the 2037 scenarios, likely due to predicted increases in traffic. The predicted maximum contribution of the project’s ventilation outlets would be 1.1 µg/m^3 in the ‘Do something cumulative 2037’ scenario at Rozelle.

At most receivers, the changes in the maximum 24-hour mean $PM_{2.5}$ concentration would be very small. The largest predicted increase in concentration at any receiver as a result of the project is predicted to be 4.2 µg/m^3, near Mowbray Road West in Lane Cove North and the largest predicted decrease is 6.3 µg/m^3, at North Sydney near Little Alfred Street. Where increases are predicted, they are greater than one µg/m^3 at less than one per cent of receivers.

Community receivers

Figure 12-18 shows the maximum 24-hour mean $PM_{2.5}$ concentrations at all the community receivers in the ‘Do something’ and ‘Do something cumulative’ scenarios. At all receiver locations, the predicted maximum concentrations were above the criterion of 25 µg/m^3, as exceedances were already predicted without the project. At all community receivers, the maximum total 24-hour concentration coincided with the highest 24-hour background concentration in the $PM_{2.5}$ profile at 49.4 µg/m^3, which is due to the extreme events described above. The combined non-background contributions to the predicted maximum 24-hour mean $PM_{2.5}$ concentration at community receivers would be relatively small. On the days when the maximum total concentration occurred, the project’s ventilation outlet contributions would be small in all cases (less than 0.2 µg/m^3).

Figure 12-19 shows the predicted changes in maximum 24-hour mean $PM_{2.5}$ concentration as a result of the project and cumulatively with other projects (the difference between the ‘Do something’ scenarios and the ‘Do minimum’ scenarios) in 2027 and 2037. All of the increases in concentration were less than one µg/m^3. The largest predicted increase in maximum 24-hour mean $PM_{2.5}$ concentrations is 0.54 µg/m^3 at a receiver CR25 in Willoughby (Sue’s Childcare Castlevale, Willoughby East) in the ‘Do something cumulative 2037’ scenario, which is less than two per cent of the criterion for $PM_{2.5}$.

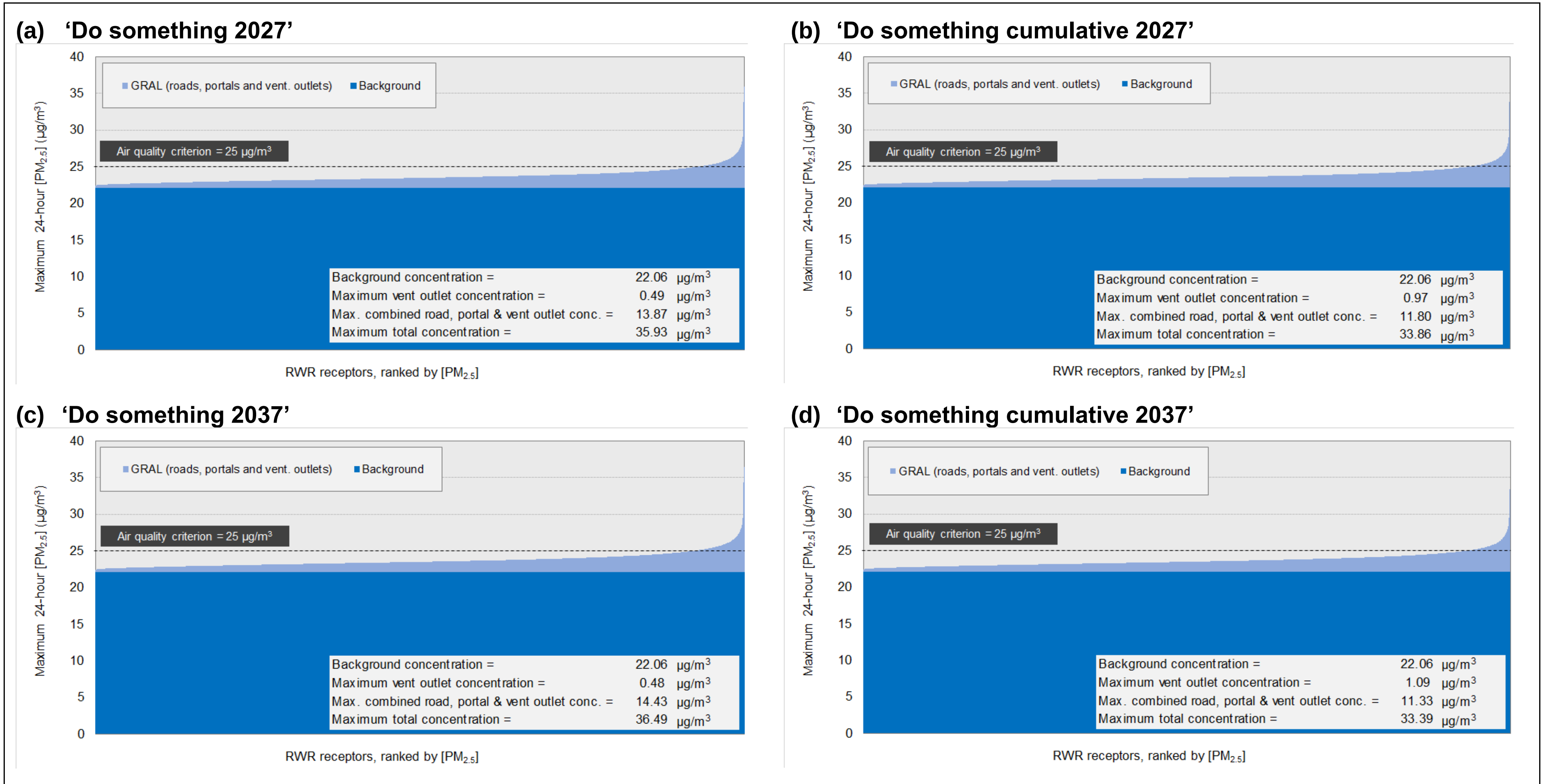

Figure 12-17 Contributions to maximum 24-hour $PM_{2.5}$ mean concentration at residential, workplace and recreational receivers

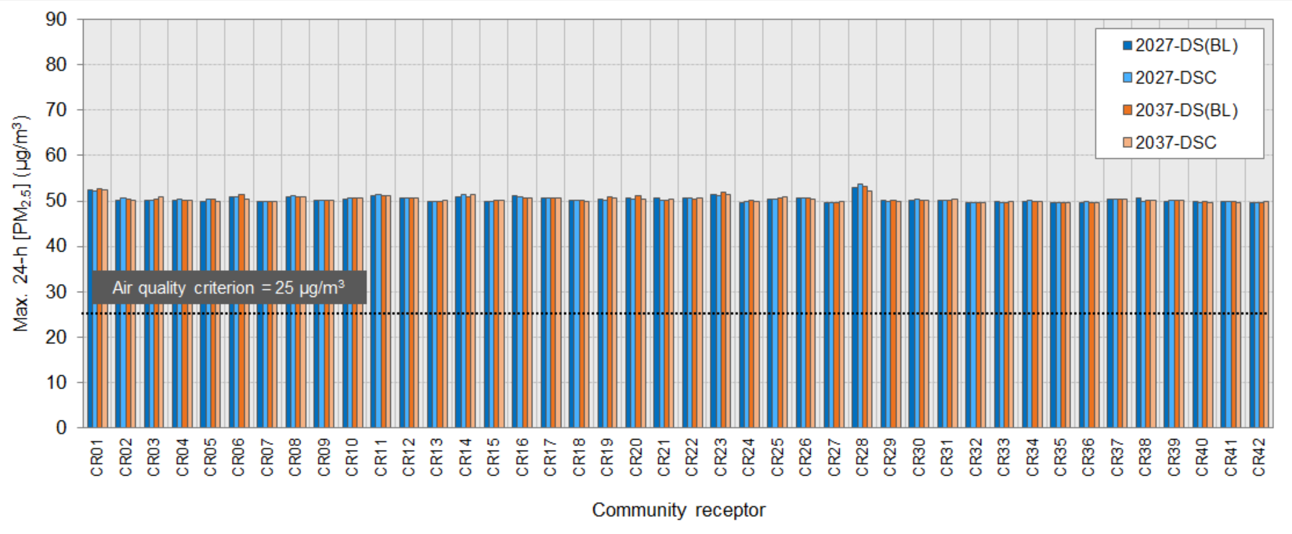

Figure 12-18 Maximum 24-hour $PM_{2.5}$ mean concentration at community receivers

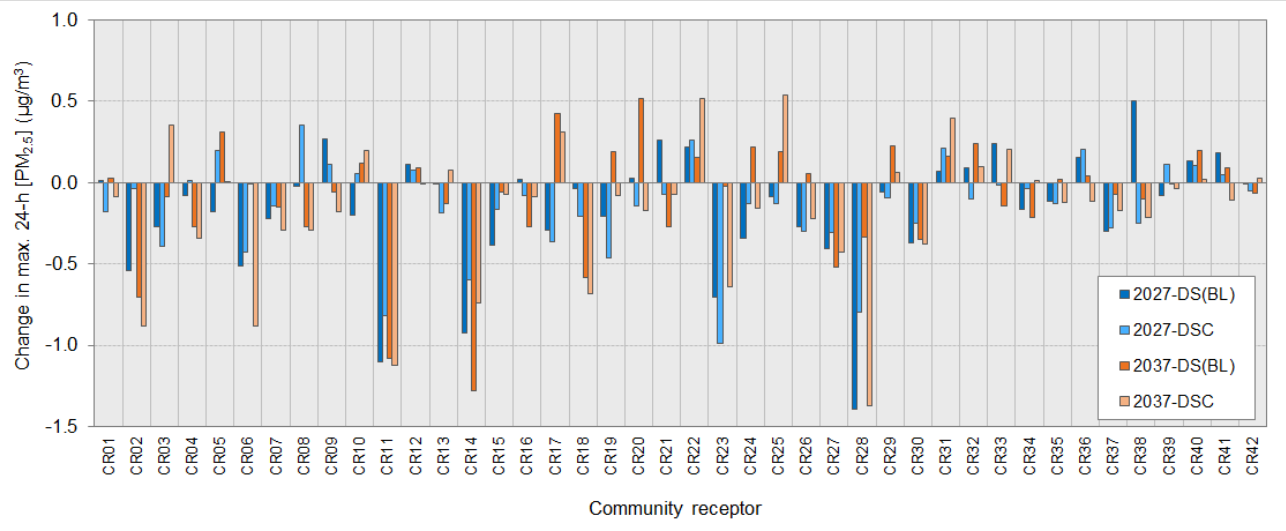

Figure 12-19 Change in maximum 24-hour $PM_{2.5}$ mean concentration at community receivers

$PM_{2.5}$ (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-20 shows predicted contributions of the project to the annual mean $PM_{2.5}$ concentration at all the residential, workplace and recreational receiver locations. Elevated background levels of $PM_{2.5}$ currently exist at these receiver locations that often exceed the criterion of eight µg/m^3, as well as the 2025 goal of seven µg/m^3. Therefore, the background $PM_{2.5}$ concentration was the main contributor to predicted annual mean $PM_{2.5}$ concentrations in the 'Do something' and 'Do something cumulative' scenarios. Nevertheless, the annual mean $PM_{2.5}$ concentration was unchanged or slightly lower at the majority of residential, workplace and recreational receiver locations in the 'Do something' and 'Do something cumulative' scenarios.

The highest predicted annual mean $PM_{2.5}$ concentration at any receiver location would be 14.5 µg/m^3. In the 'Do something' and 'Do something cumulative' scenarios, the largest surface road contribution at any receiver is predicted to be 6.7 µg/m^3. The largest predicted contribution from the project's ventilation outlets in these scenarios would be 0.18 µg/m^3, at Rozelle.

The largest predicted increase in concentration at any receiver location as a result of the project would be 1.6 µg/m^3, in Kirribilli at the northern end of the Sydney Harbour Bridge. The largest predicted decrease would be 2.3 µg/m^3, at North Sydney near Little Alfred Street. The increases were mainly along the Warringah Freeway Upgrade, north east of the Burnt Bridge Creek Deviation, along Wakehurst Parkway and particularly near the Sydney Harbour Bridge and Cammeray. The predicted increases in concentration along Wakehurst Parkway are limited to within the road corridor and do not extend out to the nearby residential, workplace and recreational receivers. There were also increases at Gore Hill Freeway, Manly Road and Rozelle.

Community receivers

Figure 12-21 shows the annual mean $PM_{2.5}$ concentrations at all the community receivers. As with the residential, workplace and recreational receivers, the annual mean $PM_{2.5}$ concentrations in the 'Do something' and 'Do something cumulative' scenarios for 2027 and 2037 would be dominated by background $PM_{2.5}$ concentrations. Given that the predicted background concentration at some community receivers (up to 7.9 µg/m^3) is already close to the air quality criterion (eight µg/m^3) under the 'Do minimum' scenario, some exceedances of the 2025 goal (seven µg/m^3) are predicted with the project under the scenarios assessed for 2027 and 2037. These exceedances also occur in the 'Do minimum' scenarios.

The contribution from surface roads is predicted to be between 0.1 µg/m^3 and 2.1 µg/m^3 whereas the largest predicted contribution from the project's ventilation outlets at any receiver would be 0.1 µg/m^3.

Figure 12-22 shows the predicted change in the annual mean $PM_{2.5}$ as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. Overall, the changes would generally be less than 0.3 µg/m^3. The largest predicted increase in annual mean $PM_{2.5}$ concentration at any community receiver as a result of the project would be 0.3 µg/m^3 at receiver CR03 (St Basil's, Annandale) in the 'Do something cumulative 2037' scenario. This increase is less than four per cent of the air quality criterion. The largest reduction in the annual mean $PM_{2.5}$ concentration (up to 1.1 µg/m^3) is predicted at receiver CR28 (Peek A Boo Cottage, Seaforth) with the project.

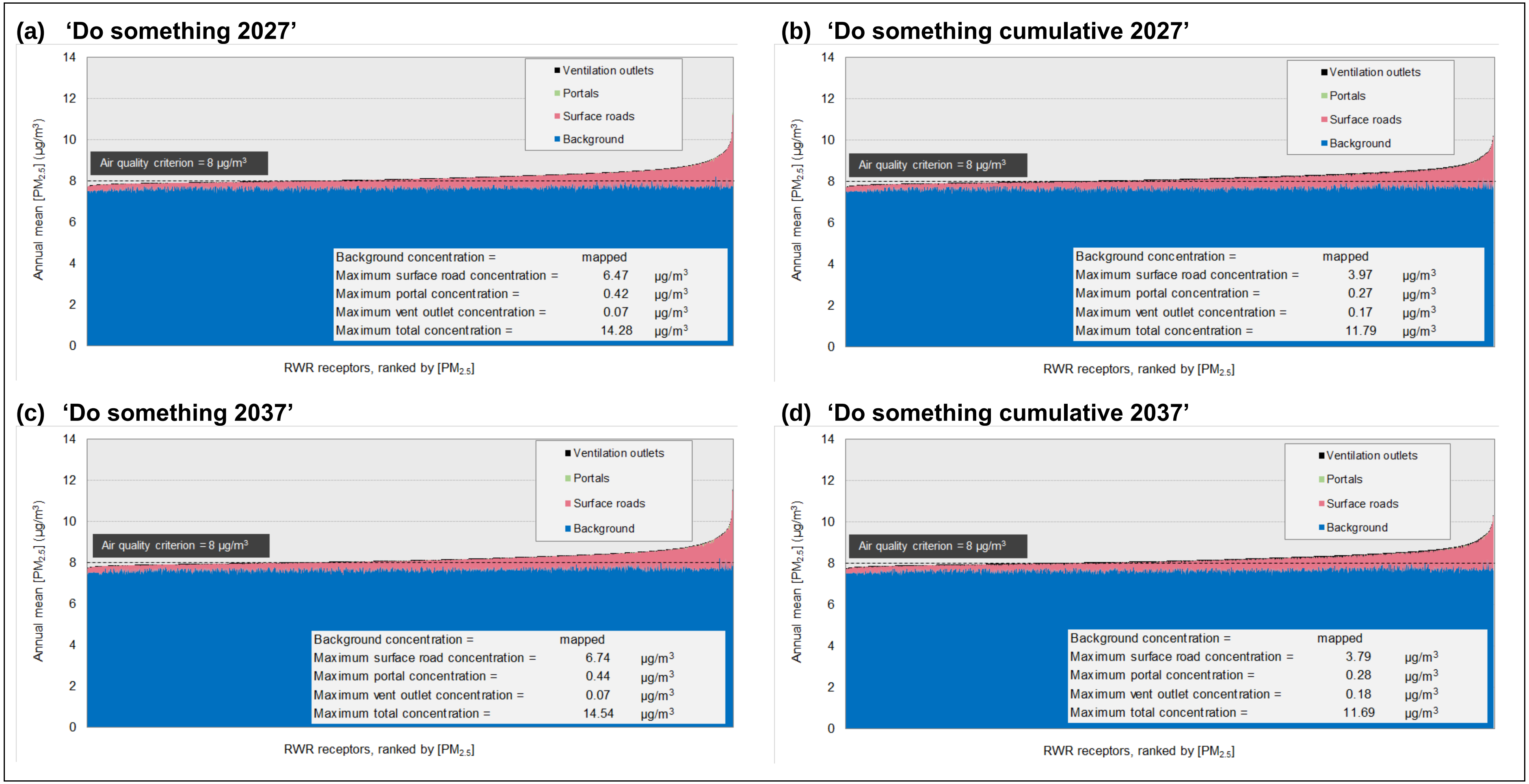

Figure 12-20 Contributions to annual mean $PM_{2.5}$ concentration at residential, workplace and recreational receivers

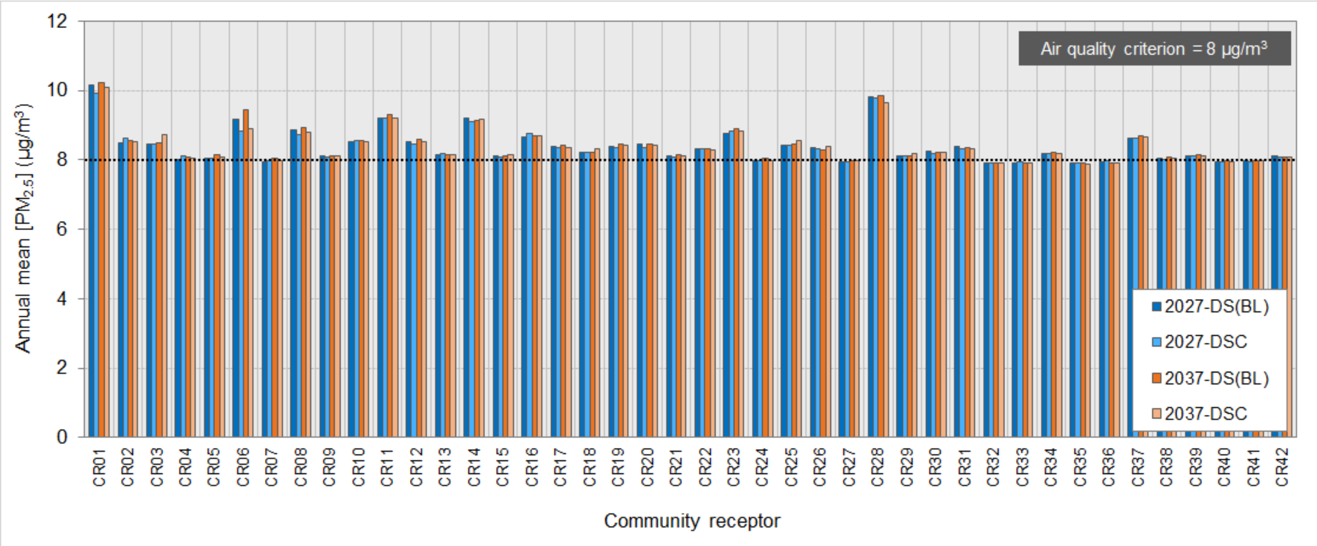

Figure 12-21 Annual mean $PM_{2.5}$ concentration at community receivers

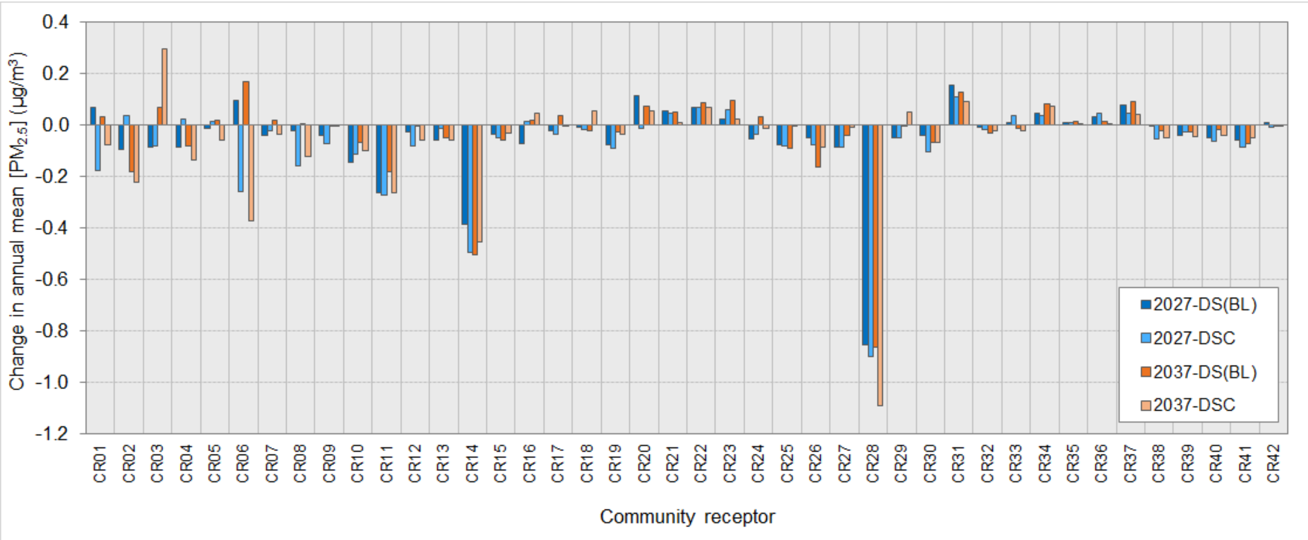

Figure 12-22 Change in annual mean $PM_{2.5}$ concentration at community receivers

Carbon monoxide (CO)

Residential, workplace and recreational receiver locations

The maximum 1-hour and rolling 8-hour mean CO concentrations are predicted to be below the 1-hour and rolling 8-hour CO criteria at all the receiver locations for all the scenarios. The highest total 1-hour CO concentration in any of the 'Do something' or 'Do something cumulative' scenarios is predicted to be 5.5 mg/m^3, in Rozelle. The largest predicted contribution from ventilation outlets at any receiver is predicted to be less than 0.1 mg/m^3, also in Rozelle. Rolling 8-hour mean CO concentrations at all of the residential, workplace and recreational receiver locations are predicted to be similar to those obtained for maximum 1-hour concentrations.

Community receivers

The CO concentration at all of the community receiver locations, is predicted to be well below the impact assessment criterion for both the maximum 1-hour and maximum rolling 8-hour mean CO concentrations.

The largest contribution of surface roads to the maximum total concentration in any of the 'Do something' and 'Do something cumulative' scenarios is predicted to be small for both the maximum 1-hour and maximum rolling 8-hour mean CO concentrations (1.2 mg/m^3 at receiver CR01 (University of Notre Dame, Broadway)). The contribution of the project's ventilation outlets to the maximum CO concentration is zero or negligible (ie less than 0.01 mg/m^3) for all receivers.

Air toxics

Five compounds, benzene, polycyclic aromatic hydrocarbons, formaldehyde, 1,3-butadiene and ethylbenzene, were considered in the assessment. These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles and have commonly been assessed for road projects.

The predicted changes in the maximum 1-hour concentrations for these compounds showed that there would be minor increases in concentrations as a result of the project, however, all air toxic concentrations would be well below their respective assessment criterions. The increases (and decreases) for the most affected residential, workplace and recreational receiver locations would be higher for those that are in close proximity to the surface roads, but in all 'Do something' and 'Do something cumulative' scenarios for all five compounds considered in the assessment, the total predicted concentrations would be well below their respective criteria. For example, the largest increase in benzene concentrations at any residential, workplace and recreational receiver location for a 'Do something cumulative' scenario is predicted to be 3.7 µg/m^3, but the total concentration of 8.7 µg/m^3 still remains well below the criterion of 29 µg/m^3 (0.029 mg/m^3).

12.6.3 Redistribution of air quality impacts

Spatial changes in air quality

The spatial changes in pollutant concentrations are assessed with respect to annual mean $PM_{2.5}$ concentration, given its importance in terms of human health risks. However, the spatial changes would be qualitatively similar for all pollutants.

The annual mean $PM_{2.5}$ concentration as a result of the project ('Do something 2027' scenario relative to the 'Do minimum 2027' scenario) is predicted to decrease along Military Road, Spit Road, Manly Road and Warringah Road. These reductions would be associated with the reductions in traffic and would result in improved amenity along these built-up road corridors. The human health benefits associated with the decrease in $PM_{2.5}$ concentration as a result of the project is discussed in Chapter 13 (Human health).

There would be increases in the $PM_{2.5}$ concentration along Sydney Harbour Bridge and Wakehurst Parkway. In the case of Wakehurst Parkway there would be a large increase in traffic (about 140 per cent) as a result of the project. However, the section of Wakehurst Parkway that is affected crosses bushland, and there are no sensitive receivers close to the road. Predicted increases in pollutant concentrations along Wakehurst Parkway are also limited to the road corridor and do not extend out to nearby receivers. There would be broadly similar changes in the 'Do something 2037' scenario.

For the cumulative scenarios, there would be some additional changes as a result of the Western Harbour Tunnel and Warringah Freeway Upgrade project, including reductions in the $PM_{2.5}$ concentration along the Western Distributor, Sydney Harbour Bridge and Warringah Freeway.

Overall, there would be no marked redistribution of air quality impacts, and there would generally be a shift towards lower concentrations. Most notably, there would be no significant increase in concentration at receiver locations which already had high concentrations in the 'Do minimum' scenarios.

12.6.4 Ambient air quality (elevated receivers)

Modelling of all pollutants at elevated receivers, for the 'Do something cumulative 2037' scenario was carried out at heights of 10 metres, 20 metres, 30 metres and 45 metres above ground level. The changes in the annual mean and maximum 24-hour mean PM_{10} and $PM_{2.5}$ concentrations were considered in addition annual average and maximum 1-hour average NO_2 concentrations and air toxics (only the incremental (ventilation outlet) contribution).The aim of this assessment is to provide an evaluation of impacts at elevated receivers within 300 metres of the project's ventilation outlets.

It should be noted that existing buildings at receiver locations are not as tall as the heights discussed above (eg at a receiver location, an existing building may be up to 10 metres in height but was assessed at all four selected heights).

As summary of the outcomes of the elevated receivers assessment for existing buildings is provided below with the full methodology and results provided in Section 8.4.9 of Appendix H (Technical working paper: Air quality):

- For the annual average PM_{10} and $PM_{2.5}$ concentrations, there are no predicted exceedances of the respective criteria at any modelled height
- For the maximum 24-hour average PM_{10} concentrations, there are no predicted exceedances of the criterion of 50 $\mu g/m^3$ at any height for the buildings present
- For the maximum 24-hour average $PM_{2.5}$ concentrations, there are no predicted exceedances of the criterion of 25 $\mu g/m^3$ at any height for the buildings present
- For the annual average and maximum 1-hour average NO_2 concentrations, there are no predicted exceedances of the criterion at any modelled height
- For the maximum 1-hour average benzene, PAHs, formaldehyde, 1,3-butadiene and ethylbenzene concentrations, there are no predicted exceedances of the criteria at any modelled height.

Considering the above, it can be concluded that no adverse impacts are predicted at any existing buildings.

The modelling predicted no exceedances at any modelled height for concentrations for annual average PM_{10} and $PM_{2.5}$, annual average and maximum 1-hour average NO_2 and air toxics. The assessment predicted some exceedances at heights above 30 metres within 300 metres of the project's ventilation outlets for $PM_{2.5}$ and PM_{10} maximum 24-hour average concentrations, which might impact any future buildings at these heights. This would not necessarily preclude such development and further consideration at rezoning or development application stage would be required.

In addition, land use considerations would be required to manage any interaction between the project and future development for buildings with habitable structures above 20 metres and within 300 metres of a ventilation outlet.

Transport for NSW would assist councils and the Department of Planning, Industry and Environment (as appropriate) in determining relevant land use considerations applicable to future development in the immediate vicinity of the project's ventilation outlets for inclusion in Local Environmental Plans or Development Control Plans, where required, to manage interactions between the project and future development. This may include procedures for identifying the requirement for consultation with Transport for NSW for proposed rezoning or development applications.

12.6.5 Regional air quality

The absolute changes in the total emissions resulting from the project can be viewed as a proxy for the project's regional air quality impacts which, based on the results, are likely to be negligible. For example:

- Changes in NO_X emissions for the assessed road network for the 'Do something' scenarios in a given assessment year ranged from an increase of around one tonne per year to a decrease of around four tonnes per year, depending on the scenario. In the 'Do something cumulative' scenarios, changes in NO_X emissions ranged from an increase of around 29 tonnes to 125 tonnes per year. These values equated to small proportions of human activity related NO_X emissions in the Greater Sydney airshed in 2016 (about 53,700 tonnes)
- The projected reduction in the NO_X emission rate between 2016 and 2037 (about 2000 tonnes per year) exceed the relatively small increases in the NO_X emission rate due to the project in a given year.

The regional air quality impacts of a project can also relate to its capacity to influence ozone production. The project's impact on ozone concentrations in the Greater Sydney region was assessed in accordance with the NSW Environment Protection Authority's *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). The assessment indicated that the largest increase in NO_X emissions due to the project (125 tonnes per year in the 'Do something cumulative 2037' scenario) would be above the 90 tonnes per year threshold for conducting a further detailed assessment. Further assessment using the NSW Environment Protection Authority Level 1 screening tool indicated that the maximum 1-hour and 4- hour incremental ozone concentrations due to the project in the 'Do something cumulative 2037' scenario would not exceed the screening impact level of 0.5 parts per billion, and therefore no further consideration is required.

Overall, the regional impacts of the project would be negligible, and undetectable in ambient air quality measurements at background locations.

12.6.6 Odour

For each of the residential, workplace and recreational receivers, the change in the maximum one hour total hydrocarbon concentration as a result of the project was calculated. The largest change in the maximum one hour total hydrocarbon concentration across all receivers was then determined, and this was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes, and acetaldehyde). Some hydrocarbons emitted from the burning of fuel by motor vehicles create odour. These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the NSW EPA Approved Methods, are shown in Table 12-10.

Table 12-10 Changes in odorous pollutant concentrations

Scenario	Largest predicted increase in maximum 1 hour hydrocarbon concentration		
	Toluene (μg/m³)	Xylenes (μg/m³)	Acetaldehyde (μg/m³)
'Do something 2027'	6.7	5.6	1.5
'Do something cumulative 2027'	5.9	4.8	1.3
'Do something 2037'	3.9	3.2	1.3
'Do something cumulative 2037'	3.5	2.9	1.2
Odour criterion (μg/m³)	360	190	42

12.7 Environmental management measures

12.7.1 Management of construction impacts

Environmental management measures relating to air quality impacts are outlined in Table 12-11.

Table 12-11 Environmental management measures – air quality

Ref	Phase	Impact	Environmental management measure	Location
AQ1	Pre-construction and construction	General	Standard construction air quality mitigation and management measures will be detailed in construction management documentation and implemented during construction, such as: a) Reasonable and feasible dust suppression and/or management measures, including the use of water tanks and/ or carts, sprinklers, site exit controls (eg wheel washing systems and rumble grids), stabilisation of exposed areas or stockpiles, and surface treatments b) Selection of construction equipment and/or materials handling techniques that minimise the potential for dust generation c) Management measures to minimise dust generation during the transfer, handling and on site storage of spoil and construction materials (such as sand, aggregates or fine materials) (eg the covering of vehicle loads) d) Adjustment or management of dust generating activities during unfavourable weather conditions, where reasonable and feasible e) Minimisation of exposed areas during construction f) Measures for managing odour generation likely to result in odour impacts at sensitive receivers in the vicinity during the	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			disturbance, handling and storage of potentially odorous materials, including any contingency measures g) Internal project communication protocols to ensure dust-generating activities in the same area are coordinated and mitigated to manage cumulative dust impacts of the project h) Site inspections will be carried out to monitor the effectiveness of implemented measures and identify any additional measures to be implemented.	
AQ2	Pre-construction and construction	Odour	Further site investigations will be carried out during the detailed design and construction planning phase to determine the potential to encounter odorous gases or materials during the proposed excavations at the Flat Rock Drive construction support site (BL2). If the investigations indicate that there is potential for odorous materials to be uncovered or odorous gases to be released, the potential for off-site impacts (informed by meteorological studies and modelling as required) will be investigated. If unacceptable off-site impacts are predicted, appropriate mitigation and management measures will be identified to minimise potential impacts, with consideration of the investigation results, proposed site activities and meteorological conditions, and the identified measures will be implemented during relevant site activities. Odour monitoring will be carried out during relevant site activities and mitigation and management measures adjusted as required to minimise potential off-site impacts.	BL
AQ3	Construction	General	Dust and air quality complaints will be managed in accordance with the overarching complaints handling process for the project. Appropriate corrective actions; if required, will be taken to reduce emissions in a timely manner.	BL/GHF
AQ4	Construction	Odour	Any areas of exposed material at the Flat Rock Drive construction support site that have the potential to generate odour will be kept to a minimum during site establishment works and while the area is uncovered. If odorous areas are to remain uncovered at the end of the work shift, temporary cover or other suitable measures to minimise odour emissions will be implemented.	BL

Ref	Phase	Impact	Environmental management measure	Location
AQ5	Construction	Odour	If the dredged materials require some form of land-based processing prior to disposal, an assessment of potential odour impacts will be carried out for the proposed processing site in accordance with the *Technical framework for the assessment and management of odour from stationary sources in NSW* (DEC, 2006). This will include modelling to assess whether the use of the site and the proposed processing and treatment activities for the dredged material can comply with a criterion of 2 odour units at all sensitive receivers in the vicinity.	BL
AQ6	Construction	Odour	Where the assessment carried out in environmental management measure AQ5 indicates that compliance is not likely, an odour management strategy will be developed. The strategy will describe appropriate mitigation and management measures to ensure that the 2 odour units criterion is met, odour survey requirements and contingency actions that will be implemented if significant odour issues are observed in the vicinity of sensitive receivers. The strategy will be developed prior to accepting dredged material at the site and implemented for the duration of the processing of dredged material at the site.	BL

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection

12.7.2 Management of operational impacts

The Secretary's environmental assessment requirements for the project require details of, and justification for, the air quality management measures that were considered for the project. This section reviews the environmental management measures that are available for improving tunnel-related air quality, and then describes their potential application in the context of the project. The measures are categorised as follows:

- Tunnel design
- Ventilation design and control
- Air treatment systems
- Emission controls and other measures.

Tunnel design

Tunnel infrastructure is designed in such a way that the generation of pollutant emissions by traffic using the tunnel is minimised. Tunnel design provisions for this project include:

- Minimal gradients as far as reasonably practicable
- Large tunnel cross-sectional area to reduce the pollutant concentration for a given emission into the tunnel volume, and to permit greater volumetric air throughput
- Increased height to reduce the risk of incidents involving high vehicles blocking the tunnel and disrupting traffic. This would reduce the risk of higher pollutant concentrations associated with flow breakdown.

Ventilation design and control

The project ventilation system has been designed and would be operated so that it would achieve some of the most stringent standards in the world for in-tunnel air quality, and would be effective at maintaining local air quality. The design of the ventilation system would ensure zero portal emissions.

The ventilation system would be automatically controlled using real-time air velocity and air quality sensor data to ensure that in-tunnel conditions are managed effectively in accordance with the agreed criteria. Furthermore, specific ventilation modes would be developed to manage breakdown, congested and emergency situations.

There are several reasons why a tunnel needs to be ventilated. The main reasons are:

- Control of the internal environment: It must be safe and comfortable to drive through the tunnel. Vehicle emissions must be sufficiently diluted so as not to be hazardous during normal operation, or when traffic is moving slowly or stationary
- Protection of the external environment: Ventilation, and the dispersion of pollutants, is the most widely used method for minimising the impacts of tunnels on ambient air quality. Collecting emissions and venting them via elevated ventilation outlets is a very efficient way of dispersing pollutants. Studies show that the process of removing surface traffic from heavily trafficked roads and releasing the same amount of pollution from an elevated location results in substantially lower concentrations at sensitive receivers (Permanent International Association of Road Congress (PIARC), 2008)
- Emergency situations: When a fire occurs in a tunnel, the ventilation system is able to control the heat and smoke in the tunnel so as to permit safe evacuation of occupants, and to provide the emergency services with a safe route to deal with the fire and to rescue any trapped or injured persons.

The ventilation system design options that were considered for the project are discussed in Chapter 4 (Project development and alternatives) and the system adopted for the project is described in Chapter 5 (Project description).

Air treatment systems

In November 2018, the ACTAQ, chaired by the NSW Chief Scientist and Engineer, published a review of lessons learnt from other major road tunnel projects in NSW (ACTAQ, 2018c). The review found that emissions from well designed ventilation outlets have little, if any, impact on surrounding communities and, as such, there is little health benefit in installing filtration and air treatment systems.

There are several air treatment options for mitigating the effects of tunnel operation on both in-tunnel and ambient air quality. Where in-tunnel treatment technologies have been applied to road tunnels, these technologies have focused on the management and treatment of particulates.

ACTAQ's review of options for treating road tunnel emissions (ACTAQ, 2018b) demonstrated that the appropriate design of ventilation outlets would achieve the same (or better) outcomes as installing air filtration systems – that is, the contribution of tunnel ventilation outlets to pollutant concentrations would be negligible for all receivers. In Australia, tunnel projects therefore generally implement the primary approach of dilution of air pollution (through ventilation systems) (PIARC, 2008; Centre d'Etudes des Tunnels (CETU), 2016).

Emission controls and other measures

In addition to the operation and management of the tunnel ventilation system, there are various operational measures available to manage in-tunnel emissions and air quality. These include the following:

- Traffic management: Traffic management will be employed by tunnel operators to control exposure to vehicle-derived air pollution. Measures can include (PIARC, 2008):

- Allowing only certain types of vehicle
- Regulating time of use
- Tolling (including differential tolling by vehicle type, emission standard, time of day, occupancy)
- Reducing traffic throughout
- Lowering the allowed traffic speed

- Incident detection: Early detection of incidents and queues is essential to enable tunnel operators and the highway authority to put effective traffic management in place. Monitoring via CCTV cameras is normally a vital part of the procedure for minimising congestion within tunnels and allowing timely operator response to changes in traffic flow
- Public information and advice: Traffic lights, barriers, variable message signs, radio broadcasts, public address systems (used in emergencies) and other measures can help to provide driver information and hence influence driver behaviour in tunnels
- Cleaning the tunnel regularly assists in reducing concentrations of small particles (PIARC, 2008), as is common practice in Sydney tunnels.

Further design development of the in-tunnel air quality monitoring system will be carried out during future project development phases and will include the following:

- Air quality monitoring of key pollutants will be carried out throughout the tunnel. The locations of monitoring equipment will generally be at the beginning and end of each ventilation section. This will include, for example, monitors at each entry ramp, exit ramp, merge point and ventilation exhaust and supply point. The location of monitors will be governed by the need to meet in-tunnel air quality criteria for all possible journeys through the tunnel system, especially for NO_2. This will require sufficient, appropriately placed monitors to calculate a journey average
- Velocity monitors will be placed in each tunnel ventilation section and at portal entry and exit points. The velocity monitors in combination with the air quality monitors will be used to modulate the ventilation within the tunnel to manage air quality and to ensure net air inflow at all tunnel portals.

During operation, air quality monitoring data will be made publicly available on the new motorway website.